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CONTENTS

Relation of Hedgerows in Winter to Wildlife in Central New York (Pls. 21, 22) ..... *George A. Petrides* 261

Gathering, Transplanting, and Care of Young Antelopes (Pl. 23) ..... *A. A. Nichol* 281

Winter Habits of White-tailed Deer in Central New York (Pl. 24) ..... *David B. Cook and W. J. Hamilton, Jr.* 287

Identification of Sex in Live Muskrats (Pls. 25, 26) .. *Herbert L. Dozier* 292

Color Sex Ratios, and Weights of Maryland Muskrats ..... *Herbert L. Dozier and Robert W. Allen* 294

Muskrats on the Texas Coast (Pls. 27, 28) *Daniel W. Lay and Ted O'Neil* 301

Apparatus for Marking Wild Animals with Colored Dyes (Pl. 29) .. .. *James Moffitt* 312

Fisheries Investigations in Crater Lake, Oregon, 1937–1940 ..... *Arthur D. Hasler and D. S. Farner* 319

Winter Relations of Bobcats to White-tailed Deer in Maine ..... *Merwin A. Marston* 328

Caching and Recovery of Food by the Western Fox Squirrel ..... *Victor H. Cahalane* 338

Winter Rodent Populations in Field-Shocked Corn .... *J. P. Linduska* 353

Title Page, Contents, and Index, Volume 6 ..... *Supplement*

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THE JOURNAL OF WILDLIFE MANAGEMENT

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RELATION OF HEDGEROWS IN WINTER TO WILDLIFE IN CENTRAL NEW YORK[1]

George A. Petrides

Many authors recognize the importance of hedgerows[2] to wildlife on farmlands, and recently the planting of hedgerows on contours has been urged for conserving both soil and wildlife. The form and composition of hedgerows, however, is imperfectly known, and this study was undertaken to determine for farmlands in central New York state: (1) the inter-relationships between the plant communities of natural hedgerows and their animal inhabitants in winter, and (2) the most desirable types of contour hedgerows for maintenance of maximum wildlife populations and for control of soil erosion.

This study was conducted near Cornell University, at Ithaca, New York, chiefly from October 1, 1939 to April, 1940, on two dairy farmland areas, at altitudes of 1,000 and 1,100 feet, on the low hills of that section.

Both areas included many hedgerows in all stages of development. The first plot of about 500 acres, included more than two linear miles (11,500 feet) of hedges. This farm was composed of pasture lands (59%), abandoned fields (11%), woods and brush (15%), hay (7%), buckwheat (3%), wheat (2%), and miscellaneous areas (3%). Its agricultural use fell in Land Class IV.[3] The second area, of 150 acres, with 4,400 feet of hedgerows, comprised buckwheat (45%), hay (17%), wheat (12%), pasture (11%), corn (4%), abandoned fields (8%), and orchard (3%) and was typed as Land Class III. The common soils of the areas, were shallow Canfield silt loam and Dunkirk silty clay loam over a shale bedrock.

THE HEDGEROW HABITAT

Types.—Evidence of plant succession was inferred from the associations present. It was thought possible to designate four different types of hedgerows, each at a different stage in plant succession and of characteristic height, density, and plant composition. These are termed "herb stage," "shrub stage," "small-tree stage," and "tall-tree stage" hedges.

The herbaceous stage had much low

[1] From a thesis in the Graduate School of Cornell University, Ithaca, N. Y., for the degree of Master of Science (June, 1940).

[2] A hedgerow is here defined as any narrow lane of plant growth on uncultivated strips between farm fields. Some authors use the term fencerow for a strip of land primarily supporting herbaceous plants. Hedgerow, hedge, and fencerow here are used synonymously.

[3] Land classification of New York State farmlands is based upon the prosperity of the tenants as reflected by outward appearances. Lands range through classes I–VII; classes III–VII are those capable of profitable agriculture (La Mont, 1937).

herbage and scattered seedlings of woody species. It was often completely buried by snows and of little value to wildlife in winter. It apparently develops into the shrub stage that is of great worth in providing fruits, browse, and low, dense cover for wildlife. Evidently the shrubs in time give way to small trees that shade out the lower species, decreasing the density of plant growth near the ground and reducing available food and cover. This third, or small-tree stage, in turn, is eventually dominated by large climax forms of the tall-tree stage. The last has slight value for wildlife save where unusual conditions permit growth of an under-story of shrubs or vines. There thus seem to be but four hedge-row types, but under normal field conditions, intergrades are more common than typical examples, and parts of one hedge may fall into different categories.

For this study, plants up to 10 feet tall were termed shrubs, those reaching to 20 feet as small trees, and higher ones as tall trees. The stage of plant succession in a hedgerow thus was determined roughly by average height. This method indicated the current stage of development but yielded little knowledge of future conditions. Many small individuals of a tall species could be present in a hedge and yet be inconspicuous due to equality in height with the shrubs present. The plant succession in such a case might alter greatly in a short time. The obvious criterion for estimating the rapidity with which one growth stage might succeed another, therefore, is the plant composition of the existing stage.

The species indicative of succeeding growth stages are present as the coming generation in existing hedges, as in the 13 hedgerows at various stages summarized in Table 1.

TABLE 1

PLANT SPECIES IN 13 HEDGEROWS, BY PERCENTAGES, ACCORDING TO GROWTH HABITS

Plants	*Hedge Stage*			
	Herb	*Shrub*	*Small tree*	*Tall tree*
Herbs	63.3	1.4	1.9	—
Shrubs	21.6	47.2	30.1	16
Small trees	15.1	42.2	27.7	18
Tall trees	—	6.9	18.7	54
Vines	—	2.3	21.6	12

It may be concluded that, under the field conditions studied, three stages in plant succession lead finally to hedgerows of tall trees. Throughout this development, species characteristic of later stages in succession are all represented in the current phase though not dominant. Hence where it is desired to preserve wild hedgerows in a particular sub-climax growth stage it is necessary to determine the plant species present and weed out those capable of eventually overtopping the desired plants.

Hedgerow Composition.—The plant composition of a hedgerow determines its value to wildlife, for upon this factor depends the density and height, and the fruits and browse available to fulfill the cover and food needs of wild birds and mammals on farms.

The study areas included 54 plant species in 27 woody hedgerows totalling 15,480 feet in length. Chokecherry (*Prunus virginiana*) and red-panicled dogwood (*Cornus candidissima*) formed almost half the total volume of plant material present (sight estimation of volumetric abundance; Table 2); six species made up half of the balance, and 46 species comprised the remaining

quarter. Those comprising less than 0.5% of the total volume are listed by name only (Table 3). Their occasional great importance to wildlife, however, is pointed out later in this paper.

ground, but the small-tree and tall-tree stages were successively less so, save as shrubs and vines supplied low growth.

Common plants of extreme value in

TABLE 2

RELATIVE PROPORTIONS OF PRINCIPAL PLANT SPECIES IN 27 HEDGEROWS

Scientific name	Common name	Frequency of Occurrence		Percentage by bulk		
		Number of hedges in which present	Percentage	Area 1	Area 2	Both areas
Prunus virginiana	Chokecherry	26	93.2	25.6	38.0	28.5
Cornus candidissima	Red-panicled dogwood	20	76.9	26.5	1.7	19.4
Ulmus americana	American elm	22	80.5	7.8	11.5	8.8
Crataegus sp.	Hawthorn	15	54.9	7.6	1.8	6.0
Viburnum dentatum	Arrowwood	5	18.3		15.5	4.3
Prunus serotina	Black cherry	13	47.6	2.0	7.0	3.4
Carya ovata	Shagbark hickory	10	36.6	2.2	5.7	3.1
Vitis (mostly vulpina)	Grape	12	44.0	2.7	2.4	2.5
Prunus pennsylvanica	Fire cherry	11	40.3			1.6
Rubus occidentalis	Black raspberry	9	32.9			1.5
Rhus typhina	Staghorn sumac	7	25.6			1.1
Viburnum lentago	Nannyberry	4	14.6			1.1
Acer saccharum	Sugar maple	3	11.0			1.0
Rubus idaeus	Red raspberry	3	11.0			1.0
Fraxinus americana	White ash	9	32.9			0.8
Celastrus scandens	Bittersweet	6	22.0			0.6
Tilia americana	Basswood	4	14.6			0.6

Cover.—For wildlife, farm hedgerows serve primarily as permanent protecting cover on lands otherwise deficient in plant growth. According to Leopold (1937a), the most essential property of plants for winter wildlife cover is dense foliage or branches so matted as to exclude predators. He says that, to be effective, such "cover for either escape or shelter must be close to the ground."

In the hedgerows studied, density near the ground was closely associated with hedge height. Herb-stage hedgerows varied in density according to the time of year and in winter were mostly covered by snow. Shrub-stage hedges were normally quite dense near the

the hedgerows studied were red panicled dogwood (*Cornus candidissima*), grape (*Vitis*), arrowwood (*Viburnum dentatum*), and nannyberry (*Viburnum Lentago*). Alone of the taller species, hawthorn (*Crataegus*) retained its density near the ground despite maturity. As one of the most dense thorny plants on the study areas, it was of great value despite eventual growth to small-tree size.

Shrub stage hedgerows and shrub and vine species almost alone provided dense cover near the ground. The maintenance of a shrubby condition is essential for hedgerows to be of permanent cover value to wildlife.

TABLE 3

LESS IMPORTANT PLANT SPECIES IN 27 HEDGEROWS

Scientific name	*Common name*	*Number of hedges in which present*
Acer rubrum	Red maple	2
Apocynum	Dogbane	1
Betula lutea	Yellow birch	1
Carpinus caroliniana	American hornbeam	1
Carya cordiformis	Bitternut hickory	1
Cornus stolonifera	Red-osier dogwood	1
Corylus cornuta	American hazelnut	1
Dipsacus sylvestris	Teasel	1
Hamamelis sylvestris	Witch hazel	1
Juglans cinerea	Butternut	1
Juniperus virginiana	Red cedar	2
Lonicera tartarica	Tartarian honeysuckle	1
Lonicera xylosteum	European fly-honeysuckle	4
Malus pumila	Apple	4
Menispermum canadense	Moonseed	1
Ostrya virginiana	Hop hornbeam	1
Parthenocissus quinquefolia	Virginia creeper	1
Parthenocissus vitacea	Thicket creeper	3
Pinus rigida	Pitch pine	2
Pinus strobus	White pine	3
Populus tremuloides	Quaking aspen	2
Pteridium latiusculum	Bracken	1
Pyrus communis	Pear	2
Quercus borealis	Northern red oak	3
Quercus velutina	Black oak	1
Rhus Toxicodendron	Poison ivy	3
Rosa	Rose	2
Rubus alleghaniensis	Blackberry	3
Rubus odoratus	Flowering raspberry	1
Sambucus canadensis	Common elderberry	5
Smilax herbacea	Greenbrier	1
Smilax hispida	Greenbrier	1
Solidago	Goldenrod	3
Viburnum acerifolium	Maple-leaved viburnum	1
Zanthoxylum americanum	Prickly ash	1

Food Plants.[4]—Food for wildlife was present in hedgerows as fruits and browse. Of all the plants in the hedges studied, only 24 species were seen in fruit, and only 11 of them in appreciable quantities. Chokecherry, red-panicled dogwood, and hawthorn produced the bulk of the fruit crop; these dropped most of their fruits during October, but the remnant retained provided late winter food in small amounts on most of the study areas. The height of snow drifts in hedgerows often enabled rabbits and pheasants to use fruits six or seven feet above the ground.

The extremely abundant fruits of chokecherry were consumed by white-footed mice; pheasants and red squirrels also took them. (Notes on black cherry (*Prunus serotina*) were not separated from those for chokecherry.) Red-panicled dogwood drupes were eaten by pheasants and bluebirds, and rabbits and red squirrels exhibited a liking for hawthorn fruits. Throughout the winter, grape vines retained many dried fruits which pheasants ate late in February.

The fruits of hawthorn and apple

[4] Detailed accounts of food utilization are included in the sections treating of the animals studied.

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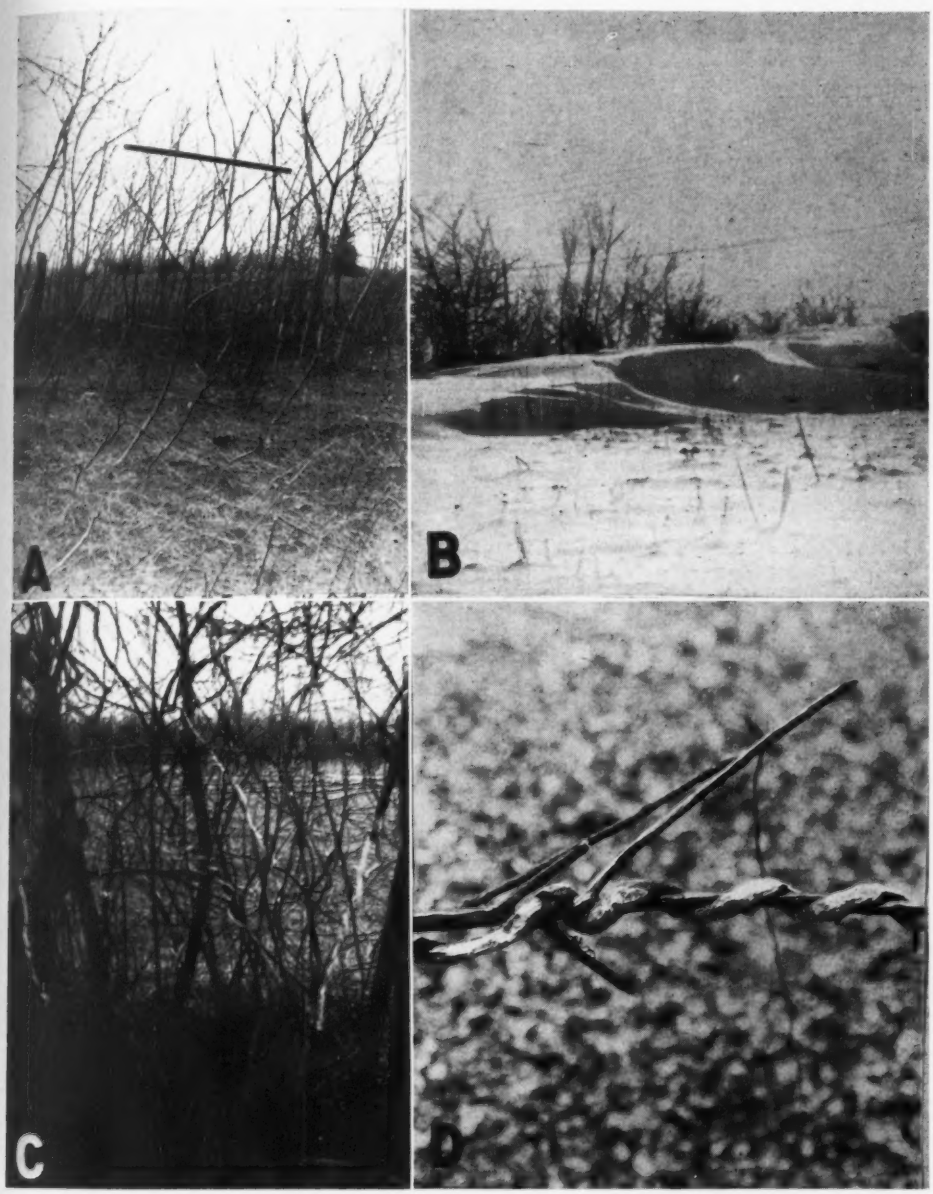
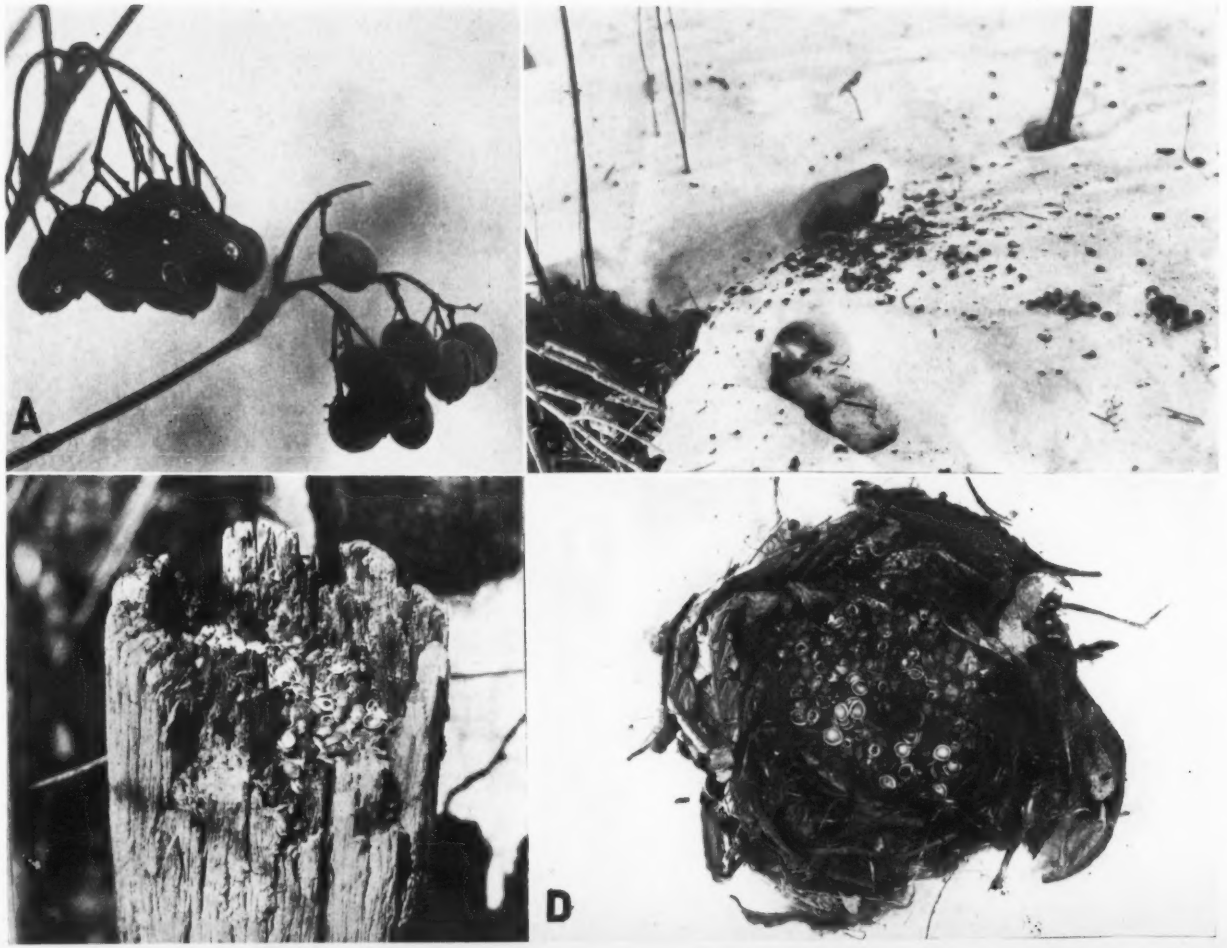


A. Height of rabbit-browsed twigs in shrubs indicated by yardstick. *B*. Deep snow drifts commonly permitted rabbits to browse as high as six feet above the ground in hedgerows. *C*. Bark and soft wood of bittersweet vines consumed by cottontails. *D*. Bittersweet browse is preferred to chokecherry by cottontail rabbits.



A. Fruits of nannyberry, about ⅔ natural size. *B*. Snow burrows of the red squirrel under nannyberry plants, with fruit refuse heaps and rabbit droppings. *C, D*. "Kitchen middens" of white-footed mouse. Remains of chokecherry fruits were present in nearly every decayed fence post and bird nest in the hedgerows.

A. Fruits of nannyberry, about ⅔ natural size. *B*. Snow burrows of the red squirrel under nannyberry plants, with fruit refuse heaps and rabbit droppings. *C*, *D*. "Kitchen middens" of white-footed mouse. Remains of chokecherry fruits were present in nearly every decayed fence post and bird nest in the hedgerows.

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(*Malus pumila*) dropped early, but were reached throughout the winter by rabbits and ring-necked pheasants where winds had blown them free of snow, and by red squirrels through burrowing. Hawthorn was of great value in supplying several wild species with fruits and browse. Nuts of shagbark hickory (*Carya ovata*) were collected and utilized extensively by red squirrels in one hedge. Some species, such as arrowwood and bittersweet (*Celastrus scandens*) produced fruits abundantly but these dropped before the critical late winter period. They were not noted as eaten by wildlife. Staghorn sumac (*Rhus typhina*), rose (*Rosa*) and nannyberry held their fruits throughout the winter or until eaten. Chickadees and crows consumed sumac fruits, red and gray squirrels ate seeds of the nannyberry, and discarded fleshy portions of the fruits of the latter were used by cottontail rabbits.

Plants of white ash (*Fraxinus americana*), Virginia creeper (*Parthenocissus quinquefolia*), thicket creeper (*P. vitacea*), poison ivy (*Rhus toxicodendron*) and greenbrier (*Smilax herbacea*) were few; their fruits persisted somewhat through the winter, but none was recorded as used by wildlife. Fruits of seven other species were available only through September, and were not of value during the winter.

It is significant that of the 24 plant species noted in fruit on the study areas, only three species cannot be included in vine, shrub, or small-tree classifications. Likewise, of the 22 hedge species browsed by cottontail rabbits (noted beyond) only three are not of these types. Evidently hedgerows predominantly of plants of these growth habits are most valuable to wildlife for production of winter foods.

HEDGEROW BIRDS

Field observations by Dr. Arthur A. Allen and the author provided a list of 93 bird species seen in hedgerows about Ithaca during recent years. The majority of these were only transients in migration or wanderers from other habitats. Sparrows predominated, in species and individuals, among birds that typically frequented hedgerows, comprising 12 of 17 species resident either in summer or winter. Typical hedgerow birds were:

Ring-necked pheasant (*Phasianus colchicus torquatus*)
Catbird (*Dumetella carolinensis*)
Brown thrasher (*Toxostoma rufum*)
Robin (*Turdus migratoribus*)
Yellow warbler (*Dendroica aestiva*)
Purple finch (*Carpodacus purpureus*)
Goldfinch (*Spinus tristis*)
Savannah sparrow (*Passerculus sandwichensis*)
Vesper sparrow (*Pooecetes gramineus*)
Slate-colored junco (*Junco hyemalis*)
Tree sparrow (*Spizella arborea*)
Chipping sparrow (*Spizella passerina*)
Field sparrow (*Spizella pusilla*)
White-crowned sparrow (*Zonotrichia leucophrys*)
White-throated sparrow (*Zonotrichia albicollis*)
Fox sparrow (*Passerella iliaca*)
Song sparrow (*Melospiza melodia*)

Hedgerow Birds in Winter.—One study area was censused for birds from late October through February (Table 4). It consisted entirely of arable land, and hedgerows provided the only woody cover; 7,400 feet of hedgerows were cruised on each census. Along lines of travel without hedges, one horned lark (*Otocoris alpestris*) was the only bird seen during the season.

TABLE 4

CENSUSES OF BIRDS SEEN IN HEDGEROWS

	10/25/39	10/29/39	11/ 1/39	11/ 8/39	11/17/39	11/22/39	12/ 1/39	12/ 8/39	12/13/39	12/18/39	1/ 5/40	1/23/40	2/23/40	Totals
Tree sparrow		11	8	16	7		2		1	1			14	60
Song sparrow	3	11	33	1										48
Junco	23	5	17											45
Vesper sparrow		3	8											11
Robin	3	2												5
Pheasant		1			2					1				4
Mourning dove								4						4
Goldfinch				3										3
Fox sparrow	1	1	1											3
White-crowned sparrow	2													2
Downy woodpecker		1			1									2
Ruby-crowned kinglet			2											2
Chickadee					1				1					2
Field sparrow			1											1
Savannah sparrow														1
Unidentified sparrows	7	12	10	1							8			37
Totals	39	47	80	21	11	0	2	4	2	2	8	0	14	230

From Table 4 it is evident that: (1) the bird population of the area was concentrated in the hedgerows; (2) tree sparrows, song sparrows, and juncos were the most numerous as individuals; (3) the fall migration of sparrows reached its peak about November 1; and (4) only a small flock of tree sparrows occupied the area throughout the winter. The lack of birds on the area was apparently due to deep snows which covered all but a little of the ragweed and buckwheat present.

Survey of Bird Nests.—From October 26 to November 4, the bird nests in the hedgerows were counted, the identity of their former occupants ascertained, and details as to the locations used were noted. The hedges were searched just after most of the leaves had fallen and thereafter, so all nests present were probably recorded.

An attempt was made to estimate the population of nesting birds in the hedgerows from the number of nests found, but the results probably indicate only a minimum, inasmuch as some nests may have fallen earlier and others on the ground were destroyed or hidden. The fresh appearance of the nests seen and the exposed nature of hedgerow nest sites, led to the belief that no arboreal nests remained from previous seasons. Nests of any one species within 200 feet of each other were considered to have been constructed by the same pair of birds.

In 15,425 feet of hedgerows, 42 nests were found, or one per 367 feet, indicating a population of 30 pairs, as follows:

	Pairs	*Nests*
Catbird	10	16
Robin	7	9
Field sparrow	6	7
Song sparrow	3	6
Goldfinch	1	1
Unidentified sparrow	1	1
Red-eyed vireo	1	1
Yellow warbler	1	1

Data for nest sites included the plant species utilized, nest height, plant

height, and hedge width (Table 5). A ratio was obtained by dividing the percentage of nest abundance by that of plant abundance. A ratio greater than 1.0 indicates a nesting preference.

TABLE 5
NEST SITES OF HEDGEROW BIRDS

Plants used	*Catbird*	*Robin*	*Field sparrow*	*Song sparrow*	*Unidentified sparrow*	*Goldfinch*	*Red-eyed vireo*	*Yellow warbler*	*All birds*	*Percentages of nests*	*Percentages of plant abundance*	*Ratio: percentage nests/percentage plant abundance*
Crataegus	5	3	1	2		1		1	13	30.9	6.0	5.1
Cornus candidissima	3		4	1	1				9	21.4	19.4	1.1
Prunus virginiana	1	1		2			1		5	11.9	28.5	0.4
Sambucus canadensis	2								2	4.7	0.5−	9.4+
Celastrus scandens		2							2	4.7	0.6	7.8
Malus pumila	1								1	2.4	0.5−	4.6+
Smilax herbacea			1						1	2.4	0.5−	4.6+
Vitis	2		1	1					4	9.5	2.5	3.8
Rhus typhina	1								1	2.4	1.1	2.2
Prunus serotina		2							2	4.7	3.4	1.3
Viburnum dentatum	1								1	2.4	4.3	0.6
Ulmus americana		1							1	2.4	8.8	0.3
Total nests	16	9	7	6	1	1	1	1	42	100		

Hawthorn was decidedly the most preferred for nesting of the three most abundant plants in the hedges. It formed but 6.0% of the plant material present, yet 13 (31%) of the nests were located in it. In contrast, chokecherry comprised 28.5 per cent of the total plants present but contained only 5 (12%) of the nests, seeming thus to be shunned by most birds. Red-panicled dogwood was apparently intermediate. Grape, bittersweet, and elderberry furnished outstandingly acceptable nesting sites.

Considering the growth characteristics of the plants selected for nesting, it is obvious that dense species were preferred by most birds. Furthermore, robins and catbirds usually sought the centers of dense hedges. Other species were at home in dense situations along hedge borders. This latter fact may explain the apparent preference of field sparrows for red-panicled dogwood which, in dense hedges, often grew only along the edges. This plant seemed to be shunned by robins, probably because it lacked a firm support for their heavy mud nests. The greatest aggre-

TABLE 6
NEST SITES OF HEDGEROW BIRDS

	Number of nests	*Average nest height (feet)*	*Average plant height (feet)*	*Average hedge width (feet)*
Catbird	16	5.4	8.0	13.5
Robin	9	6.6	12.0	12.3
Field sparrow	7	3.6	5.3	6.8
Song sparrow	6	3.7	4.8	10.5
Goldfinch	1	4.5	6.0	1.0
Yellow warbler	1	6.5	8.0	17.0
Red-eyed vireo	1	4.0	5.0	12.0
Unidentified sparrow	1	1.0	2.0	18.0
All nests	42	5.0	7.5	11.0

gation of nests was in the densest hedges. Great density at the nest site is apparently of prime importance.

Tall trees in hedges contained no nests. Low average nest and plant heights were preferred by all birds; sparrows especially selected nest sites near the ground. Narrow hedgerows were more acceptable to sparrows than to other birds, but hedges more than 10 feet wide harbored birds of all species.

Winter Feeding Habits of Song Birds.—During January to March, interpretation of tracks in the snow supplemented direct field observations in determining the foods and feeding methods of hedgerow songbirds. Tree sparrows were then the only species regularly present in the hedges, but flocks of goldfinches were seen occasionally and horned larks were sometimes common in open areas.

The sparrows fed near the borders of fields. Hedgerows furthered their distribution throughout the otherwise open regions and permitted them to feed on areas that otherwise probably would not have been reached. The zone within 100 feet of a hedgerow was most thoroughly fed over, and the strip within 50 feet was especially favored. The distance from hedgerows that flocks of sparrows travelled into fields seemed to depend upon a combination of several factors. The most obvious of these were:

1. Time of day. Birds resting or feeding in a desultory manner remained in or close to a hedge. During regular feeding periods, and especially in the early morning, the flocks covered as great an area as permitted by other conditions.

2. Depth of snow. As snow became deeper and food scarcer, a greater feeding range from the hedgerows became necessary.

3. Density of field cover. Ordinarily the denser the cover, the further the penetration into it. This factor was necessarily subordinated to No. 2, however, when food became scarce in late winter.

4. Height of nearest neighboring cover. Depending especially upon No. 3, the feeding range seemed to be increased as the height of the hedge or other nearby woody cover was greater.

Feeding flocks of sparrows, without exception, paralleled hedges in their movements. If undisturbed, they progressed in a definite direction, the hindmost members flying over others to drop into the flock near its forward edge. A continuous rolling movement was thus set up that enabled rapid progress over a feeding ground.

On January 10, a flock of about 75 goldfinches fed in a field of wheat stubble containing a thin growth of common ragweed. This field was surrounded on three sides by hedgerows and, while under observation, the flock covered the field on those three sides, feeding in the 100-foot strip nearest the hedgerows. They progressed about 500 feet along one side of the field in ten minutes and the remaining distance at a corresponding rate. Had the density of food on the feeding ground been greater, doubtless this speed would not have been attained.

The thoroughness of sparrows in consuming available food seemed to vary with the species. Tree sparrows seemed to search for food much more diligently than goldfinches; the latter seemingly enjoyed a greater range, appearing but occasionally on the hedgerow plots.

Tree sparrows used hedgerows for escape and as roosting or loafing grounds between feedings. When danger threatened, as when a hawk flew overhead or the observer made a sudden move, feeding flocks retired hastily to the shelter of the nearest hedgerow even through the observer was thereby more closely approached.

The foods eaten by winter songbirds were occasionally ascertained by direct observation or as indicated by tracks and associated signs. Most important were achenes of the common ragweed (*Ambrosia artemisiifolia*), which was moderately common in many fields and remained erect through heavy snowfalls. Tree sparrows fed on the lowermost seeds while standing on the surface of the snow and jumped for those out of reach. They were not seen to perch on the plant itself as was the habit of the goldfinches. Ragweed was much patronized by birds until it was buried by snow.

Tracks indicated the utilization of chicory (*Chichorium Intybus*) by both sparrows and horned larks during late February and March, when snows permitted the reaching of its heads and when the ragweed was buried. So far as investigated, however, fruits of good food value seemed to be lacking in these heads.

Of the fruits of woody plants in the hedges, those of the red-panicled dogwood were noted as eaten by bluebirds on October 1. During late February and March, crows consumed many staghorn sumac fruits. Their tracks were found in profusion on several occasions about the bases of sumac plants; fruit "bobs" had been torn down apparently by them, and partly eaten on the surface of the snow. Droppings of crows were sometimes associated with tracks; on two occasions these consisted entirely of sumac seeds and their hairy coverings. Despite the crows, however, the quantity of sumac fruits in the hedges was not seriously depleted.

Ring-necked Pheasant.—The pheasant (*Phasianus colchicus torquatus*) was the only game bird on the areas. Records were kept of flushes, tracks, and food habits to learn its use of hedgerows. The local distribution of pheasants in winter was evidently controlled by food rather than the cover present. During the fall, when food was plentiful and dense roosting cover unnecessary, pheasants were generally distributed. With the advent of the hunting season, however, they remained only in one overgrown area with good cover and with food available in a nearby abandoned orchard and small corn patch. The place most favored was a hedgerow connecting the corn patch with a brushy gully. The scarcity of readily available food during late winter caused these pheasants to travel along hedgerows seeking fruits. Lack of food because of small crop acreage was the greatest factor in restricting the range of pheasants on the study areas.

The general nature of this study made it impossible to investigate pheasants in all habitats, especially since the birds were scarce after October. The winter cover preferences of 69 pheasants flushed were as follows:

Cover	*Quitted*	*Sought*
Hedgerows	34	22
Weeds and grasses	18	30
Buckwheat	7	0
Corn	4	0
Brush	2	6
Woodland	4	3
Unknown	0	8

About half of the birds were flushed from hedgerows (including those fright-

ened from within 10 feet of hedges) but the more intensive observation of hedgerows probably resulted in a disproportionate number of birds being noted in that environment. The escape cover chosen, however, was probably not similarly affected; more than a third of those flushed sought shelter in hedges.

Some authors minimize the importance of fencerows in pheasant production because of predation upon hedgerow nests. Randall (1940) in Pennsylvania found a high mortality in hedgerow nests, especially by predation. In Michigan, Wight (1930) states that predation on nests is of little importance; nevertheless he decries fencerows as safe crowing or nesting grounds since nesting is induced either in adjoining hay, soon to be mown, or along a line of travel of predators.

In contrast, Leopold (1937b) tentatively concludes that in either thickly or thinly populated areas "more fencerows . . . appear to be a sounder way to save nests than more flushing bars." He reports predation a small factor, as compared with mowing, in nest mortality. Similarly, Randall (1940) found most April nests in fencerows and along roadsides. He also located more nests where hedgerows were common and agrees with Leopold that hedgerows are preferred to alfalfa or clover as nesting grounds.

A suggestion as to the basis for this diversity of opinion is found in the report by Yeatter (1934) on the Hungarian partridge. He found that "23.5 per cent of the nests along roadsides, where they are usually restricted to a strip 10 or 15 feet wide," were broken up by predators, whereas "41 per cent of all nests along narrow fencerows" were similarly destroyed. He advocates preservation of hedgerows and grassy strips more than 10 feet wide and destruction of narrow strips of vegetation in efforts to decrease nest predation affecting this species.

During extensive study of the pheasant in Pennsylvania, Randall obtained data from which he drew similar conclusions. He states (personal letter) that "nests along railroad rights-of-way were more often successful than were fencerow nests. Probably the greater success of railroad bank nests is due to the fact that the strip in which they were situated is wider than that in which most fencerow nests were located. I am also of the opinion that a greater percentage of nests succeed in wider fencerows."

Tracks of dogs, foxes, and other predators were commonly found along the edges of hedges and only exceptionally had the dense center zone been penetrated. The data at hand show the superiority of wide hedgerows in providing preferred nest sites and giving nesting birds better chances for survival.

A few records of the use of hedgerows by pheasants in feeding were made. Fresh droppings taken on October 13 at several roosts in lush streamside growth contained 229 seeds of red-panicled dogwood, 14 of hawthorn, and part of an acorn. These foods were rarely present there except in hedgerows. Droppings collected on February 17 contained seeds of red-panicled dogwood, hawthorn and grape (pulverized in contrast to the whole seeds seen previously) and tracks in the snow revealed that the birds had made a sys-

tematic search among the hedgerow plants for dried fruits of both red-panicled dogwood and grape. Despite these records, the hedgerows were obviously deficient in late winter food for pheasants. Throughout March many tracks and pecked apples were found beneath trees of an old orchard, away from hedges, where winds had blown the frozen fruits free of snow.

HEDGEROW MAMMALS

A dozen species of mammals inhabited the hedgerows. Their activities were studied mainly by observations of tracks in snow from late December until early the following April; other observations were made through the entire period from September onward. Tracks were occasionally seen in the fields, but were concentrated in the hedges and the latter evidently determined the distribution of many mammals.

Cottontail Rabbit.—The cottontail (*Sylvilagus floridanus mearnsii*) was the principal game mammal present. The hedges provided food and shelter permitting this species to live among fields covered by deep snow. Throughout the winter rabbit sign on farmlands was almost entirely confined to hedgerows. No rabbits were seen during the morning hours of January, February or March but abundant tracks and droppings indicated activities there at other times of day. So far as observed, the cottontails used woodchuck holes exclusively for shelter during the months of low temperature and constant snow cover; many burrows were kept open through four to five feet of drifted snow (Plate 21B). No rabbits were started from "forms" after December 5. No trapping or tagging was done, but field observations afford several conclusions as to use of woodchuck burrows by the cottontails:

1. Tracks in fresh snow and changes in range indicated that cottontails lived singly during the winter months.
2. Burrows in brush or woodland were preferred to those in hedges. The latter were used in early winter, but abandoned later although the hedge rows that contained them often continued to be utilized as feeding areas.
3. Several burrows within the cruising radius of a cottontail were used during early winter, but during later months of more severe weather and deepened snow, only one was kept open.
4. In burrow systems with more than one entrance, the several entrances used during early winter were reduced to one with the coming of deep snow.
5. After each snowstorm, rabbits dwelling in hedgerows gradually increased their daily ranges to maximum distances of from 300 to 700 feet from the burrows, possibly by gradual use of food brought within reach as each storm added to the height of the hedgerow drift.
6. Hedges devoid of woodchuck holes were not used as living quarters by rabbits during the winter months, although some were visited as feeding and travel areas.
7. Rabbits preferred burrows in hedgerows of the shrub or small-tree stages with good density near the ground.

So far as observed, winter rabbit foods were confined to browse and fleshy fruits. Doremus (1938) found that the shoots of basswood, black raspberry, blackberry, and black cherry and the bark of apple were consumed in

large quantities near Ithaca. Todd (1927) found the most important food items at Syracuse, New York, to be bark of staghorn sumac, and shoots of bass-

TABLE 7

INTENSITY OF RABBIT BROWSING

(*I, sparse; II, moderate; III, extensive*)

Plants	*General environment (Doremus)*	*Hedgerow environment (Petrides)*	*Total plant volume in hedges (per cent)*
Carpinus caroliniana	—	II	trace
Carya ovata	II	I	3.1
Celastrus scandens	I	III	0.6
Cornus candidissima	I	I	19.4
Corylus cornuta	—	I	trace
Crataegus	I	III	6.0
Hamamelis virginiana	—	I	trace
Malus pumila	III	III	trace
Parthenocissus quinquefolia	I	—	trace
Prunus serotina	III	I	3.4
Prunus virginiana	I	I	28.5
Rhus toxicodendron	I	III	trace
Rhus typhina	II	III	1.1
Rosa	I	III	trace
Rubus alleghaniensis	III	III	trace
Rubus idaeus	I	III	1.0
Rubus occidentalis	II	III	1.5
Rubus odoratus	—	I	trace
Sassafras officinale	—	III	trace
Smilax hispida	I	III	trace
Solidago	II	I	trace
Ulmus americana	I	I	8.8
Viburnum Lentago	I	—	1.1
Vitis	I	II	2.5

wood, red-osier dogwood, bittersweet, and black raspberry. In the hedgerows of the present study, the bark and shoots of staghorn sumac, apple and bittersweet and the twigs and small branches of hawthorn, rose, poison ivy, sassafras, and greenbrier were preferred, although none of these species was common in the hedges. Poison ivy and prickly greenbrier were so attractive to rabbits that practically every shoot not covered by snow was consumed.

In the work of Doremus (1938), browse species taken by cottontails were studied in six areas, covering a wide variety of habitats. The use of food plants by rabbits in the general environment as recorded by Doremus, and of the same species in hedgerows as observed during the present study are compared in Table 7. Of bittersweet, apple, and staghorn sumac, the bark and soft wood of smaller branches and stems, as well as shoots, were eaten. For all other species, only twigs were cropped. The abundance of the plants in hedgerows is indicated as a percentage of the total volume; those less than 0.5% are listed as traces.

Of the 54 plant species in the hedges, only 22 were browsed. The remainder included 4 herbaceous species, early snowed under, and several others that occurred only as trees. It is striking that the species present in greatest abundance were browsed only slightly, whereas others low in total volume were more intensively cropped in the hedgerows than in the general environment.

As to damage to wildlife food species by rabbits, chokecherry and red-panicled dogwood produced most of the fruit in the hedges, but were little browsed. Hawthorn, another important food plant, was intensively eaten in some areas and some small seedlings were destroyed. Grape vines were but slightly damaged, though some whole plants were killed. Nannyberry was not browsed and neither rose nor shagbark hickory were seriously damaged. Staghorn sumac was a favorite food and a considerable number of plants were destroyed. The greatest damage, however, was to apple and, particularly, bittersweet (Plate 21, D); most plants of these species in hedges were girdled.

Protecting snowdrifts prevented severe use of poison ivy and greenbrier but permitted browsing of the tops of moderately tall plants. In one instance, a 5-foot drift in a hedgerow allowed rabbits to take the entire tops of 6 and 7-foot sassafras, hazelnut, and hornbeam saplings (Plate 21, A), a desirable natural control of tree species. In general, the fruit-producing plants of hedgerows were little damaged by rabbit browsing.

Several fleshy fruits of the hedgerows were eaten by rabbits in winter. Probably the most interesting instance occurred through the agency of red and gray squirrels (see also Petrides, 1941). Several large nannyberry shrubs, bearing hundreds of fruits, formed part of a hedge that extended to a woodlot. On January 9 squirrels had come out of the woods to feed on the fruits which they split, extracted and ate the flat seeds, and discarded the fleshy exterior portions. The resulting refuse littered the snow beneath the plants and was piled on the tops of nearby fence posts and at the mouths of burrows in the snow.

By January 18 the fruits had been entirely stripped from the plants. From tracks and droppings it was evident that cottontails had consumed the fragments rejected by the squirrels. The hundreds of rabbit droppings beneath the nannyberry shrubs were of characteristic spherical shape, but slightly smaller than normal, of gray color and putty-like in consistency.

Fruits of hawthorn were likewise taken and in early winter cottontails banqueted on thorn-apples that carpeted the ground beneath the plants. Even during the period of snow from January 10 to February 23, abundant tracks, droppings, and partly-eaten fruits indicated a continuance of the habit where winds exposed the fallen fruits about the bases of the plants. The height of hedgerow drifts on the last date also permitted rabbits to obtain fruits persisting on branches up to 4 feet above the ground. On January 11, rabbits were noted to have eaten fleshy portions of hawthorn fruits left at the entrance of a small snow burrow system of a red squirrel.

Few apples were produced in the hedgerows, but several old trees in fields were much visited by cottontails from January 18 to March 28, and toothmarks of rabbits were plain on fallen fruits blown free of snow. The cottontails studied did not seem to need additional winter foods.

Dogs were the only predators known to harass the rabbits on the study areas, but all their attempts to dig out woodchuck holes in the rocky soil were apparently unsuccessful.

Woodchuck.—No woodchucks (*Mar-*

mota monax rufescens) were active during the winter but hedges were surveyed to determine their use by woodchucks for burrows and the situations preferred in hedges. This was done after the hedge leaves had dropped, but before any snow had fallen. The ages of the burrows were not estimated and an obvious group of entrances was considered as one den.

In 29 hedges totalling 16,600 feet in length, 63 dens were located averaging one per 263 feet of hedge. Nine of these hedges, 5,060 feet in length had no burrows so that dens in the other hedges averaged 183 feet apart. The width of hedge at 59 holes was as follows:

Hedge width (feet):	3	4	5	6	8	10	12	15
No. of dens:	1	2	3	15	6	6	15	11

Twelve of the 15 dens listed where the hedge was less than 6 feet wide were in a hedge between two pastures; this may have resulted in more burrows than were warranted by the width of the hedgerow. This premise is open to question but a general conclusion seems permissible that wide hedgerows are more conducive to concentration of woodchuck burrows than narrower ones. Hedges under 6 feet wide contained only 6 (11%) of the total number of burrows. The presence of rocks also has a possible influence on the location of burrows, being found at 48 (81%) of the 59 holes. Seven (12%) other burrows were at the bases of trees or fence posts and 4 (7%) were dug in more open places.

Many open areas were available for burrow locations had they been preferred by woodchucks, and rocks were present in the non-utilized, burrowless hedges, more than 85 per cent of which were 6 to 15 feet wide. Many dens in open fields with no protective objects nearby indicated the variable habits of this animal.

In a hedge-planting program designed to eliminate woodchucks, the above data suggest a narrow hedge devoid of rocks, stumps, or large trees. Converse qualifications might encourage the animals. As previously mentioned, much use is made of woodchuck burrows by cottontail rabbits and the value of the woodchuck in relation to other game should be considered in any program affecting its welfare.

Gray Squirrel.—Despite an affinity for forested areas, individual gray squirrels (*Sciurus carolinensis leucotis*) were seen several times travelling in hedgerows connected with woodlots, and tracks and middens indicated occasional foraging there. Two were seen in hedgerows at 1,500 feet and 1,100 feet respectively from the nearest wooded area. One hedge of tall trees connecting two woodlands 940 feet apart, was much used in travelling between them. An arboreal transit between these woods seemed easily possible, but the tracks indicated a preference for moving on the ground, without reference to the high hedgerow. This travel lane theoretically permitted complete utilization of the woodlots by squirrels of both areas.

As earlier noted, the gray squirrels and red squirrels, between January 9 and 18, completely harvested the crop of nannyberry fruits of several hedge shrubs at 50 to 125 feet from a woodlot, but ate only the seeds. Remains of many drupes were associated with squirrel droppings on the tops of fence posts, about the mouths of snow bur-

rows, and on the surface of the snow. Tracks of both red and gray squirrels were seen, the latter more commonly. Snow burrows were numerous and extensive beneath the plants, but were attributed to red squirrels. Seton (1925) makes no mention of the gray squirrel using snow burrows.

Apples were eaten by gray squirrels on January 18 and March 9.

Red Squirrel.—Like the gray squirrel, the red squirrel (*Tamiasciurus hudsonius loquax*) was seen in hedgerows away from its preferred woodlands. It aided in removing the crop of nannyberry fruits from a hedgerow, and constructed a network of burrows (Petrides, 1941) in the snow drift beneath the plants (Plate 22, B). Middens indicated consumption of the seeds of this plant in the mouths of the burrows. Remains of shagbark hickory nuts and hawthorn fruits were seen at other burrows. The former had evidently been collected from under the snow, and the latter were taken from the plants. Fleshy remains of fruits of nannyberry and hawthorn discarded at the snow burrow entrances were eaten by cottontail rabbits.

In one hedgerow, red squirrels established themselves for the winter in a system of woodchuck and chipmunk burrows beneath several 35-foot shagbark hickory trees. The range of the residents of this colony was considerable. After one day's activity on a fresh fall of snow, tracks revealed that one individual had travelled 3,600 feet along the hedgerows to the westward, and at the limit of its travel was 1,200 feet from its den. Tracks to the east indicated a journey of 2,700 feet, to 1,350 feet from the home burrow. The latter individual had climbed every shrub containing a bird nest and investigated remains of cherry seeds left within them by white-footed mice. It was obviously searching for food, but despite six nests overturned, the length of journey indicated probable failure. The west-bound squirrel passed five nests without investigating them.

White-footed Mouse.—White-footed mice (*Peromyscus leucopus noveboracensis*) were important competitors of larger animals for the fruit crop of the hedgerows. In practically every bird nest and on top of every fence post in a hedgerow (Plate 22, C, D) accumulations of cleaned and gnawed chokeberry seeds and of mouse droppings indicated the great extent of this harvest by the mice. Most cherry fruits were collected when they were abundant, but remains of persistent fruits were found as late as February 23 on the surface of the snow amid tracks of white-footed mice. Despite the abundance of hawthorn fruits, several bird nests in plants of this species were, nevertheless, filled completely with remains of cherry seeds. Only a few hawthorn seeds were present.

Signs of white-footed mice were found in nearly all the hedges studied, but investigation of such factors as the destruction of nestlings (Hamilton, 1940) and the taking of insects injurious to food plants, must be undertaken before the relation of this species to other wildlife in hedgerows can be correctly ascertained.

Meadow Mouse.—Practically none of the succulent foods enjoyed by the meadow mouse (*Microtus p. pennsylvanicus*) occurred in the woody hedges. Meadow mouse tracks were moderately

common in the fields, but were lacking in the hedgerows except as the mice crossed through. Cherry stems are often girdled by meadow mice, but this was not noted in the hedgerows studied.

Dog.—Tracks of domestic dogs, the commonest local carnivores, were concentrated in the hedgerows, which afforded both hunting grounds and travel lanes. Little evidence of destruction of wildlife by these animals was found on the areas, but it is likely that they are always a potential danger.

Fox.—No fox tracks were noted until March when they became moderately common. From these it was apparent that foxes often followed hedges for considerable distances and paused on the crests of snow drifts to look about. Their tracks were occasional in the fields, but a definite preference for the hedges was indicated. Nothing was determined of the food habits of the fox on the areas, but it may be an important predator at other seasons.

Skunk. Tracks of the skunk (*Mephitis nigra*) were first noted early in March in open fields where their early wanderings were apparently without regard to hedgerows. Several woodchuck burrows in woodlots were inhabited by skunks but none in the hedgerows were so occupied.

White-tailed Deer.—Two bucks (*Odocoileus virginianus borealis*) ran along a hedgerow when startled from an overgrown orchard on December 18, and droppings were found in a cornfield at 10 to 30 feet from a hedge not on the study areas, after the snow melted in May. Hedgerows are evidently occasionally utilized by deer in travelling and probably in browsing.

Weasel.—On March 28, tracks of a weasel (*Mustela*) in a hedgerow paralleled those of a white-footed mouse for some distance before becoming covered by drifted snow.

Chipmunk.—Two chipmunks (*Tamias striatus lysteri*) were seen October 29 in the hedgerow area where the red squirrel colony was established, but not thereafter. The activities of chipmunks at other seasons, particularly in the storage of food, is probably important to other animals of hedgerows.

RECOMMENDATIONS FOR HEDGEROW MANAGEMENT

Except in a few muck areas, tall windbreaks are of little value in soil erosion control about Ithaca where erosion by water, and not wind, is more important. Furthermore, tall hedgerows compete with adjacent crops for light, moisture, and soil nutrients. Conversely, contour hedges of low shrubs provide effective dams against water erosion on slopes, are easily kept from spreading into fields, function to some extent as windbreaks, and provide fruit, browse, and cover for wildlife. Natural shrub-stage hedges usually contain many small specimens of tall plant species that are capable of later overtopping and shading-out shrubs. Where shrub-stage hedgerows are to be preserved it is necessary to weed out or top species of greater potential height before they become too large.

Tall-tree species such as shagbark hickory, white ash, apple, basswood, and American elm reached a height of 10 feet in about 10 years as shown by growth rings of 26 specimens examined in the hedgerows studied. Small-tree species, such as chokecherry and hawthorn varied from 11 to 20 years in age,

and averaged about 15 years old upon reaching that height (growth rings of 15 specimens examined). Eventual replacement of shrubs by trees is inevitable in central New York if tall-tree and small-tree species are not removed at least every 10 and 15 years, respectively. Use of such valuable trees as apple and hawthorn is practical only where provision for height control is made. A primary principle in hedgerow management should be the protection of shrub species through control of competing forms.

It seems axiomatic that hedges should be composed primarily of shrubs, but care must be taken to include species of sufficient height. A minimum of 6 feet assures protection for wildlife during deep snows (drifts 3 to 5 feet deep were common in the hedges during the severe winter of study), and a maximum of 10 feet provides suitable nesting sites for most farmland songbirds.

The optimum for wildlife is a rather wide hedge whereas for adequate soil erosion control, the width varies according to slope, soil, precipitation, and methods of cultivation. Wider hedgerows provide food and cover for wildlife in greater amount and better distribution; for control of soil erosion, the increased amount of ground cover and root tangle of wide hedges insures greater efficiency.

For the welfare of songbirds and game animals, hedgerows 12 to 15 feet wide are necessary; where woodchucks and rabbits are pests, narrow hedgerows must be adopted to the detriment of all wildlife. Hedgerows at least 12 feet wide are recommended for best results in combined soil and wildlife conservation, although the prejudices of farmers may be practical barriers to their installation.

Plant species of great density are desirable in hedgerows, but the total amount of cover provided is of greater importance. The less dense the plant species comprising a hedgerow, the wider the hedgerow should be. Great density near the ground gives best protection to both wildlife and the soil. Where hawthorn is not objectionable and can be kept in a shrubby condition, it is ideal from this standpoint. Red-panicled dogwood, frost grape (*Vitis vulpina*), arrowwood, and nannyberry are also dense hedge plants of the region.

With few exceptions, the food for wildlife in the hedgerows studied was provided by shrub and vine species. Of fruit-producing species, only nannyberry and staghorn sumac retained any appreciable quantity throughout the winter. Red-panicled dogwood, hawthorn and grape are excellent cover, have desirable growth habits, produce abundant fruits, but retain few through the critical period for wildlife. The dearth of available food during late winter was believed to be the most important factor limiting the carrying capacity of the hedges. Shrub species that retain their fruits and that bear fruits of high food value but unattractive to wildlife until periods of great want occur, are badly needed in hedgerows of the Ithaca region.

From data by various authors (Anon., 1939; Edminster, 1939b; McAtee, 1936; Van Dersal, 1937; Wiegand and Eames, 1926), additional species found in this region that seem to possess some of these qualifications are red chokeberry (*Aronia arbutifolia*), Japanese barberry

(*Berberis thunbergii*), hawthorn (*Crataegus crus-galli*), English hawthorn (*C. Monogyna*), bayberry (*Myrica caroinensis*), fragrant sumac (*Rhus canadensis*), coralberry (*Symphoricarpos orbiculata*), and high-bush cranberry (*Viburnum trilobum*). Dwarf varieties of apple (*Malus*) may likewise prove to be of great worth.

Fruits of these species should provide adequate rations for birds, but Van Dersal (1937) lists only Japanese barberry and hawthorn as rabbit foods. Staghorn sumac and bittersweet should also yield a sufficient variety of foods acceptable to cottontails. Further desirable browse species are greenbrier, blackberry, and poison ivy (where the irritant quality of the last is not objectionable). Common hedgerow species, such as red-panicled dogwood, may serve in emergencies.

All of the above are of definite value for control of soil erosion, especially red-panicled dogwood because it forms thickets and spreads by rootstocks. Frost grape, too, provides exceptionally good soil cover. Contour hedges for erosion control could well be planned with these two species as a basis.

From this study, it is concluded that the ideal hedgerow for central New York should be composed entirely of shrubs and vines, and should be 6 to 10 feet high, 12 to 15 feet wide, and of good density near the ground. Its plant composition should be controlled so as to insure ample late winter foods and permanent form.

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SUMMARY

Natural hedgerows on two farm areas near Ithaca, New York, were studied from October 1, 1939 to April 1, 1940, to determine the interrelationships in winter between animal and plant associations and to obtain data on types of contour hedgerows most efficient in soil and wildlife conservation for central New York.

Four stages in hedgerow plant succession are described: herb, shrub, small-tree, and tall-tree stages. Food and cover for wildlife were best provided by shrubs and vines.

Of 17 bird species resident, in either summer or winter, in these hedgerows, 12 were sparrows. Winter bird populations were concentrated in hedgerows which, although deficient in late winter foods for birds, provided some provender and cover for travel, escape, and feeding in otherwise open, snow-covered country. Strips of land near hedgerows were most thoroughly hunted by feeding birds.

The 42 songbird nests remaining from the previous breeding season were at a mean height of 5 feet above the ground in plants that averaged 7.5 feet tall where the hedgerows approximated 11 feet in width. Plants of dense growth habits were preferred for nesting. Ring-necked pheasants used hedgerows for

feeding, roosting, and travel; about one-third of 69 individuals flushed sought hedgerows in escape. A review of the literature indicates that hedgerows 10 to 15 feet wide would decrease predation on pheasant nests.

Cottontail rabbits in hedgerows lived exclusively in woodchuck burrows during late winter; they shunned hedges lacking these retreats except for limited feeding. Rabbits in hedgerows browsed intensively on a few uncommon hedge plant species. Refuse of fleshy fruits collected by squirrels was consumed by cottontails in several instances. The sites of woodchuck burrows indicated a decided preferance of these animals for rocky locations in hedgerows more than 10 feet wide. Both gray and red squirrels used hedges in feeding and travelling. White-footed mice consumed large quantities of hedge fruits. Eight other mammals of less importance are discussed briefly.

The activities of both birds and mammals were greatest in low, shrub-stage hedgerows where fruit, browse and cover were most abundant. All of the species of hedgerow plants eaten by wildlife were most common in hedges of this type. Hedgerows 10 to 15 feet wide were preferred by songbirds, woodchucks, and cottontail rabbits. Plant species of great density are desirable in hedgerows, but the total amount of cover provided is of greater importance. The less dense the plant species comprising a hedgerow, the wider the hedgerow should be.

Hedgerows in the shrub stage are of most value to wildlife. In natural hedgerows, the shrubs should be preserved by removing associated species of greater potential height. For greatest efficiency in soil and wildlife conservation in the central New York region, it is recommended that contour hedges be composed entirely of shrubs and vines. They should be from 6 to 10 feet high, 12 to 15 feet wide, and of good density near the ground. Their plant composition should provide late winter foods for wildlife and be so controlled as to insure permanency of growth form. A list of plants providing for wildlife in hedgerows of this region is given.

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GATHERING, TRANSPLANTING, AND CARE OF YOUNG ANTELOPES[1]

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Big game workers are now well agreed that the most satisfactory results are obtained in restocking projects when adults and younger age classes are introduced together. Sometimes the difficulty or the cost of capturing fully grown animals makes it more feasible to use only the young. Recently in a restocking project in Arizona it was decided to move only the young for still another reason.

The Tucson Mountain Park is a county recreational area of several thousand acres west of Tucson, Arizona, at an elevation of 2,500 to 5,000 feet. The cover is of cacti and desert shrubs lightly interspersed with palatable forage grasses. When the Park was set aside, sufficient nuclei of quail, mule deer, peccaries and bighorn sheep were present to restock under the subsequent program protection and management. Prong-horn antelope (*Antilocapra americana*) had been native to the foothill portions of the area twenty-five years earlier but had disappeared, and the reintroduction of this species was desired. Animals available for restocking were on the grassland plateau in the northern part of the State, so it was decided to transplant only fawns. The young of the game herbivores have a strong tendency to remain in the vicinity where they have been fed, watered, and cared for. It was feared that if adults accustomed to open grass country were used for restocking, they would drift away from the desert scrub and cactus cover until they again found the grasslands.

This account of the capture, care, and shipping of the fawns used in this project provides some information on pronghorn behavior, and may be of help to those attempting similar projects.

Gathering

The fawns were gathered on Anderson Mesa, a high grassland plateau some 25 miles southeast of Flagstaff, Arizona, at elevations of 6,500 and 7,500 feet. As a result of overgrazing, the palatable grasses had largely been replaced by the valueless matchweed (*Gutierrezia sarothrae*) and the poisonous pingque (*Actinea richardsoni*). These two plants are so abundant as to give large portions of the Mesa a striking yellow cast in summer and fall. Other undesirable changes in the plant cover have also taken place on the Mesa. These may be in part the reason that each year antelope females work farther and farther into the juniper and yellow pine parks fringing the Mesa on the south and west. There they drop their fawns in small glades in the forest, instead of on the open treeless plateau as formerly. Possibly the does are finding in the less heavily grazed forest areas species of forage that more nearly meet their needs in pregnancy. Just before fawning, antelopes and deer make important changes in their diets.

[1] The restocking here described was done while the writer was in the employ of the National Park Service, which supplied the photographs.

The fawn drop is definitely under way by May 10, and apparently at its peak by the third week in May. At this time of year sheep bands are returning to their allotments, and antelopes in the protective fringe of timber are least disturbed. The movement from the open land to the forest is a relatively recent phenomenon, and today with reduced grazing permits and more tolerance by stockmen there is less disturbance of the animals than occurred years ago.

Four CCC boys from the N.P.S. Camp at Flagstaff were used in collecting the fawns; three of them had never seen an antelope until they went into the field, but in a remarkably short time they learned to distinguish bucks, does, and yearlings, and to recognize does which showed by their behavior or condition that they were nursing young.

Two methods were employed to locate the fawns. The first was to watch while a doe nursed her fawns and then when she had bedded them down, the observer, by keeping a close eye on the spot where the fawns dropped, could walk over and pick them up (Pl. 23). This was particularly effective in early morning and again in the evening, when antelopes, unless much disturbed, nurse their young. Very young fawns are also fed additionally during the day, but if this occurred at regular intervals the fact was not determined.

The second method was dependent for success on the observer's alertness and quickness of eye. An antelope that has fawns down and hidden will at the first unexplained disturbance or threat of danger look immediately and directly to the spot where her young are hidden, after which she concerns herself with the nature of the menace. This glance is so short and quick that the observer must in a single second determine the angle and direction, and mark the spot for seeking the fawns. By keeping his eye on the place where he judged them to be and immediately proceeding to it, he will often be successful in finding them. In any case proof that fawns are in the immediate neighborhood will shortly be provided by the doe; if her fear of man permits, she will circle the hunter, beat him to the locality, rouse her young, and be away with them at a speed of 20 to 30 miles per hour.

Two accurately measured records of the running speed of antelopes were made. The first concerns a young fawn, judged to be less than 36 hours old, that escaped one collector by the side of a road. No attempt was made to recapture the fawn since the crew was instructed not to chase fawns. The writer and another worker were sitting in a car nearby and when the fawn took off parallel to the road the car was put in motion and quickly drew opposite it. For four-tenths of a mile the fawn ran at a uniform speed of slightly more than 25 miles per hour (the speedometer was divided in only five-mile units). When the fawn first broke cover it spent a few seconds in awkward zig-zag efforts, giving every appearance of being ready to fall over before straightening out on its course. It ran considerably farther than the four-tenths mile but began to veer away from the road where it could not be accurately timed. The surface over which it ran was a mass of malpais rock, of a size often described as niggerheads.

A day or two later an old buck essayed to race the car, and for a few rods little attention was paid to him. Then the writer noticed the characteristic sinking of the animal's back which indicated that he was about to extend himself. The car was speeded up, and for one and two-tenths miles the animal ran at the rate of 45 miles an hour. The constancy of his speed was as remarkable as the pace. At no time could an appreciable variation either way from 45 miles be detected on the speedometer, until a final spurt when the buck crossed the road in front of the car. The speed of the car was not changed, and it is presumed the animal had to add something to his speed in order to cross. For fully two-thirds of this distance the race was on an upgrade steep enough to cause a car to roll back freely if not braked. The surface over which the antelope ran was densely covered with rocks to the size of a milk-bucket or larger. At no time during the race was the antelope more than 30 yeards from the car and the play of its shoulder and flank muscles was remindful of smoothly and swiftly moving shuttles. A few days later the speedometer of the car was checked and found to be accurate.

Getting the fawns safely in hand after they have been located was the greatest test of the field work. Success was dependent upon close adherence to the following instructions:

"When the location of the fawn has been spotted, go to it at a slow walk without stopping or change of pace. When the fawn itself is seen, change direction if need be *very gradually*, so as to appear to deliberately pass by. When within arm's reach, bend over with a smooth *unhurried* movement, holding one hand in readiness over the animal's shoulders to block the leap that in many cases will occur. As quickly as possible, blindfold the fawn by placing a soft bandage or large handkerchief over the eyes, crossing it under the throat and knotting it loosely behind the ears. Carry to the holding pen with the legs tucked up in a natural manner under the body. (Pl. 23, D.) Throughout every step in the procedure avoid quick or sudden movements. Also prevent struggling as it can cause internal hemorrhages."

Ten animals were wanted for the project. On the first day three fawns escaped because over-anxiety on the part of the inexperienced crew made them reach for the fawns too quickly. In the following ten days eleven fawns were collected without any further escapes.

Many of the does had gone into the edge of the timber for fawning, but they still retained the racial habit of placing their young in an open area. With few exceptions the fawns lie from sun-up to sun-down without moving, as they likewise spend the night after they have been fed, except when moved by the mother. At that time of year the sun by midday is uncomfortably warm for a person on the ground, and frosts are common at night. No shade or shelter is over the fawns, so they are subjected to great changes in temperature.

Many of the fawns are placed just below the crest of a gently sloping bank or land swell, among lichen-covered rocks or malpais niggerheads. To hunt and find antelope fawns without first

having their whereabouts disclosed by the actions of the mother is a remote possibility. They can be located by using a large crew of men, dragnet fashion, but only a small percentage of the young flushed will be caught; the disturbances and losses certain to accompany this method are contrary to good management.

TRANSPORTING

The fawns were held in camp until the youngest were at least a week old. Then they were moved in a pickup truck altered for the purpose. Individual crates are preferable for transporting wild animals, particularly antelopes, but when very young, they can be moved together successfully if proper safeguards are taken.

A wooden frame with an adjustable canvas cover was built on the truck bed, and burlap sacks, partly filled with straw, lined the interior of the frame. The sacks were fastened only along the top edge, so that if an animal was thrown against them the sacks would slip and not the animal. Clean deep straw was used for a bottom bed. A vertical extension was added to the exhaust pipe to prevent any possibility of monoxide fumes being sucked into the crate.

The haul was only 350 miles, but in that distance there was a drop of more than 5,000 feet in altitude and a rise of more than 60 °F. in temperature. The fawns were loaded in the morning at a temperature of 42° F. and unloaded in Tucson at 2:30 that afternoon at 105° F. When first put on the truck they were nervous and tramped about, but a fast swaying drive for a half-mile put them down quickly, and they rode quietly thereafter.

Dehydration is one of the "bugbears" attendant on raising and handling young wild mammals, particularly when they are being moved. Therefore, because of the heat and an extremely strong wind, three stops were made. At two of these the fawns were unloaded and fed a ration to which extra water had been added. At the third, time was taken merely to give them water since they were beginning to show signs of distress from the effects of heat and wind. In the early part of the trip a few stops were made to note signs, if any, of travel sickness.

FEEDING AND CARE

The fawns were fed at four-hour intervals until ten days of age. Then the midnight feeding was omitted and the amount of food used in it distributed among the other five feedings. This program was maintained for about another week, when the time intervals were gradually shifted until feedings were on a schedule that started at 6 A.M. and ended with a fifth and last feeding for day at 8 P.M. The beginning formula was:

Evaporated milk (Carnation or Pet preferred): 6 parts
Lime water (sat. sol.): 10 parts
Karo syrup, light: 1 part

At birth the fawns weighed from 4 to 5¼ pounds. They were given 2½ to 3 ounces apiece at each feeding. The lime water was made by simply throwing a handful of ordinary lime in a container and filling with water. As long as any lime was visible at the bottom of the container the solution remained

saturated. If the stools of the fawns became too soft the quantity of Karo was reduced. It was also decreased when the fawns became old enough to take a little solid food, and was discontinued at the end of four weeks. The fawns then averaged 7 pounds in weight. The amount per feeding was increased to 4 ounces with tap water replacing Karo syrup in the formula.

No further increase was made in the liquid ration, as the additional sustenance needed for growth and increased activity was obtained from forage and grain. The milk ration was stopped at the end of nine weeks.

Ordinary wide-mouthed nursing bottles were used for feeding. Bottles, nipples, and containers were kept sterilized. Feeding was started for each animal with the milk as near a temperature of 100° F. as possible. The muzzles of the fawns were washed after each feeding to remove waste milk.

These three factors of clean utensils, proper temperature, and clean muzzles are very important in assuring the health of the fawns.

Two colitic attacks beset the herd shortly after a change in caretakers. The first believed to have resulted because the animals had not been properly cleaned after feeding. Considerable experience with raising young mammals has shown that milk remaining around the muzzle often is a source of alimentary infections. This first attack was short-lived, oat-water with egg white helped bring the affected individuals quickly to their feet.

The second attack was more serious, and was brought on by a new caretaker believing that the fawns would enjoy their rations better cold, since the weather was hot. They were in a precarious condition, an intestinal infection was well established, and only two of the herd were able to get up. The alimentary tract of young antelopes and deer is so delicate and sensitive that no intestinal antiseptic was believed to be mild enough for them to tolerate. Purely as an experimental measure, each was given 1 tablespoon of sauerkraut juice diluted with 3 parts of water. This was followed in an hour by ½ ounce of milk and 2 ounces of lime water. Through the day each received altogether 5 tablespoonsful of the juice, and by the end of the second day all appeared in normal health. Subsequently, the sickest one of the lot had return "flare-ups," but a dose of sauerkraut juice always brought him back and ready for his next feed.

The fawns began to chew on things when they were a week old. No. 1 dairy or rabbit grade alfalfa hay was then provided for roughage, with one part of calf meal to seven parts of rolled oats for a concentrate. Salt and bone meal also were provided. All of these elements were utilized in small quantities by the time the animals were four weeks old. At six weeks of age they averaged 15 pounds in weight, and most of their diet then was of grain and hay.

LOSSES AND RESULTS

Two of the eleven fawns were malformed, and could not eliminate, and shortly died. A third was lost by a screw-worm infection, and a fourth died from an impaction resulting from having eaten sand and gravel.

The remaining seven were liberated in late summer. At sixteen months of age they were thriving and vigorous and had accommodated themselves to the desert range. Despite their hand rearing and close contact with man, enough of their wild nature had reasserted itself by the time they were ten months old to make them unapproachable.

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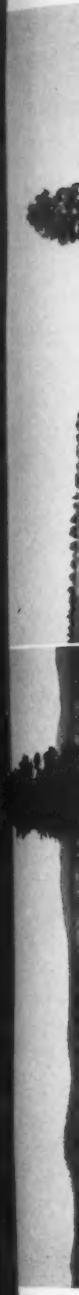
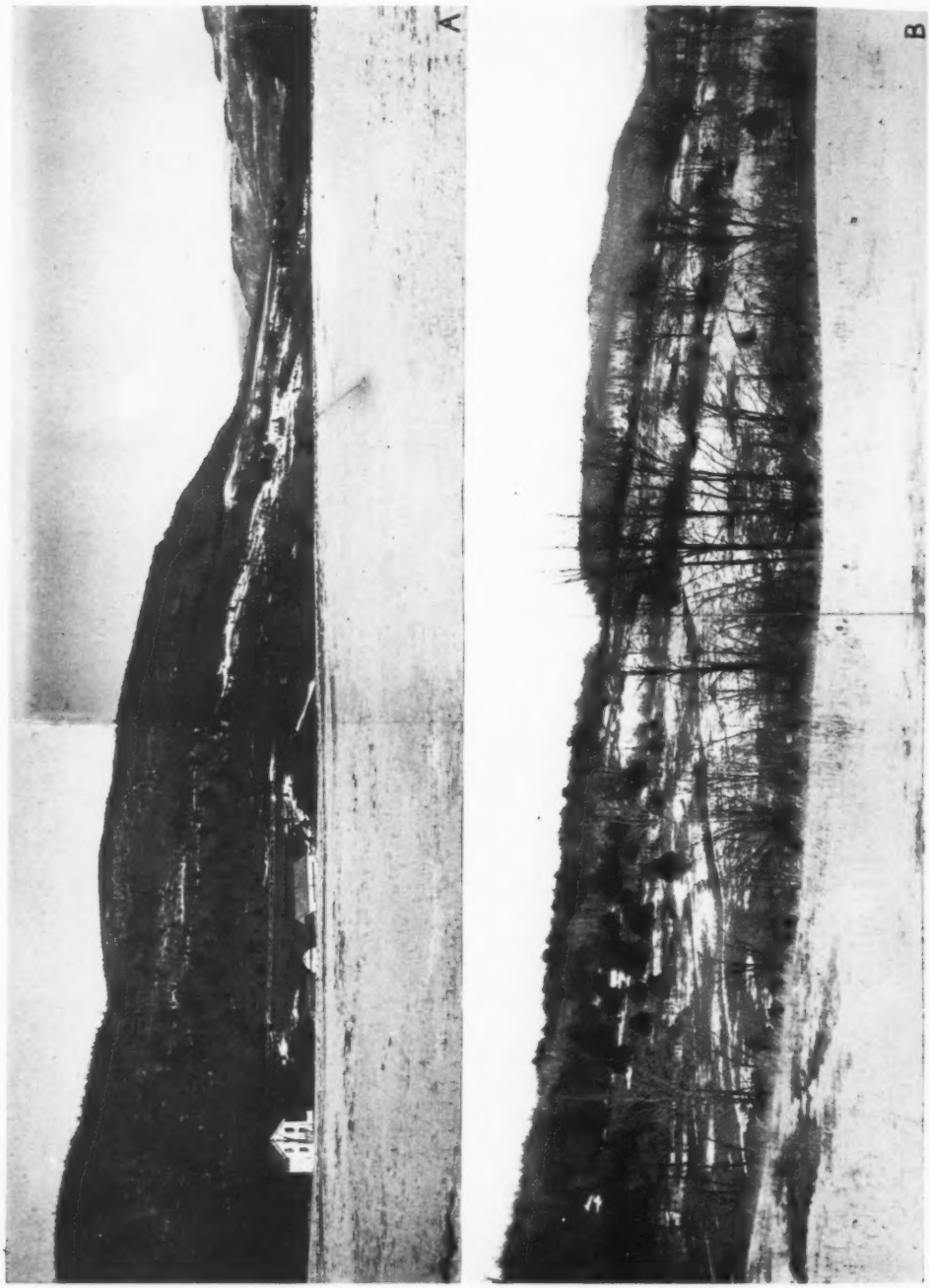


A. Typical antelope range, Anderson Mesa. Most does with fawns, were in the far fringe of forest where the fawns were collected. *B*. Typical terrain of slight curvature with malpais rock between grass and weeds where does leave fawns between feedings. *C*. Fawn as found on the ground. The low camera angle makes the animal more prominent than when usually seen. Some fawns are spotted, like those of deer, but the spots soon disappear. *D*. Proper way to carry a fawn in the field with its legs folded under the body and a bandana over its eyes.



Typical wintering areas of deer in central New York. From late January to early April they congregate on such slopes, resting in the upper mixed woods and moving down to feed. *A*. South-facing slope at mouth of the Panther Kill, Breakabeen, February, 1941. Snow covers bench in foreground and on west-facing slopes beyond Schoharie Creek far to right, but slopes in the middle distance are bare. *B*. South Slope of Turkey Hill, Ithaca, March, 1941, used by more than forty deer.

resting in the upper mixed woods and moving down to the bench in February, 1941. Snow covers bench in foreground and on west-facing slopes beyond Schoharie Creek far to right, but slopes in the middle distance are bare. *B.* South Slope of Turkey Hill, Ithaca, March, 1941, used by more than forty deer.

Fig. 2. South Slope of Turkey Hill, Ithaca, March, 1941, used by more than forty deer.

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WINTER HABITS OF WHITE-TAILED DEER IN CENTRAL NEW YORK

David B. Cook and W. J. Hamilton, Jr.

The original range of the white-tailed deer probably included all of the Northeast except the higher mountains. The densest populations doubtless were on the lower and more fertile lands, but the rising tide of white settlement pushed them back into the less hospitable mountain country. When conservation-minded people first began to make records of deer habits, the great herds of the better lands had disappeared even from men's memories and the species was known only as a dweller in remote woodlands. It is not strange, therefore, that most of the descriptions of deer wintering grounds refer to the type found in the northern coniferous forest, where softwoods predominate. Thus deer yard has come to mean a spruce-fir or cedar swamp, the dense cover interspersed with open glades and the whole traversed by a network of trails.

Few reliable records of the numbers or habits of the pre-colonial deer population of central New York are available. We do know that a considerable number of Indians procured the bulk of their meat supply from the herd without seriously depleting it. The rapid influx of white settlers that followed the Revolution, however, spelled the end for the deer, and they were exterminated there by 1880.

The territory involved, the Allegany Plateau of central New York, is a deeply-dissected tableland underlaid by flat-bedded sedimentary rocks. The topography is characterized by flat hilltops, with elevations up to 2,000 feet, and steep slopes leading down to narrow valley bottoms. The soils are moderately fertile but heavy, and tend to be thin on the hilltops. The original forest was northern hardwoods and hemlock, with pine on the drier sites. Small areas of the oak-hickory type occur on south slopes in the central and western parts. In the course of a century of agriculture, the forest of the Plateau was reduced to less than half its original area, the softwood components were sadly depleted, and the timber generally reduced in size, quality and density. Mixed farming gradually gave way to dairying. Much land has been abandoned, particularly on the hilltops, and is now reverting to brush and young timber. The farmers, with their attendant stock and dogs, have largely moved down into the valleys.

As farming declined and the areas of abandoned land increased, the deer began to repossess their former range. Substantial populations were present in the Catskill Mountains on the east and in Pennsylvania to the south, and from these centers the deer spread into the Plateau. It is impossible to assign definite dates to this influx, but as a general movement it began with the sharp agricultural decline of 1920 and has continued at an ever-increasing pace. Substantially the whole of the Plateau has been reoccupied and the deer are spreading into the lake plain to the northward. Throughout the Plateau the trend of deer population is still definitely upward.

In the Adirondacks of northern New York, a mountain area characterized by cold climate, deep snow, and a northern forest, the principal wintering areas are in evergreen swamps, where deer begin to congregate as soon as the snow becomes deep enough to make travel on the hardwood slopes difficult. In central New York, where the climate is milder and the snowfall less, the valley lands are occupied by farms and there is little or no dense softwood cover anywhere. There winter deer concentrations occur on steep south and southeast slopes apparently irrespective of the type or pattern of cover. Such slopes are sheltered from the prevailing west wind and receive the greatest amount of heat from the winter sun. As a result, the snow is seldom deep and may substantially disappear in the intervals between heavy falls, even in mid-winter (Pl. 24). We believe that the softwood swamp and the south slope, each in its own section, offer the most complete satisfaction of certain ecological requirements of the animals. Deer are notably averse to wind and to deep snow, which makes for uncertain footing and difficult travel. In the north, the dense crowns of the softwoods intercept much of the snow and serve as an excellent windbreak. In the south, the combination of topography and of even scanty woods affords adequate protection from wind, and the exposure of the slope insures rapid disappearance of each snowfall.

South slope concentration areas are known from Albany County, the most easterly in the Plateau, west at least to Cattaraugus County. Almost every suitable slope now has its herd of deer and both the number and size of the herds appear to be increasing yearly. Though the number of deer in each concentration area varies, some are known that total more than 100.

During the summer and fall, the deer population is spread rather uniformly over the suitable range. Following the mating season in November, the deer are widely scattered, occupying waste land, brushy slopes, or wooded ridges, browsing or feeding on the fallen mast. Does are accompanied by their fawns of the previous spring. The bucks usually travel alone. Occasionally, during December, a buck and several does with fawns are encountered, but these bands seldom number more than five or six. Deep snow, with attendant travel difficulties, is usually first experienced late in January. At that season, the deer begin to congregate in small bands of nine to twelve or more. They pass the day bedded on the upper slopes in fairly dense cover of hardwood and hemlock. An hour or two before sunset they commence to feed, working slowly from the timber to the lower south slopes, where thickets of sumac and viburnum and small patches of conifers or long-deserted orchards provide a measure of cover and where grassland affords abundant grazing.

Depending on the severity of the winter, the deer tend to form larger concentrations. By late February, the herds have increased materially, some numbering more than forty. By early March, when accumulated snow on the ridges has made travel difficult, the herds resort entirely to the lower slopes and valleys for feeding. They may often be seen in such situations through the day, feeding, resting, or merely moving about. They can be approached quite

closely and their feeding habits readily studied through binoculars.

Areas selected for wintering are on moderate to steep south or southeast slopes. On a concentration area at the mouth of the Panther Kill, in Schoharie County, there is a half-mile of slope with an *average* gradient of 20 degrees; many others are even steeper. On such slopes the potency of the sun's rays is roughly twice that on level land and very much greater than on north slopes. The lay of the land is such that the slopes are protected from west and north winds. The cover types include cut-over lands, young hardwoods, overgrown land, closely-cropped pastures, meadows, orchards, and a small amount of tilled land. We believe that the steepness and particularly the exposure of the slope are significant. These south- and southeast-facing hills provide the best protection from wind and the maximum of insolation, with resulting higher temperatures and minimum snow depth. On March 6, 1936, two herds of 20 and 23 deer were observed feeding on the south slope of Turkey Hill, near Ithaca, New York. The temperature at 11 A.M. was 20° F.; at the same time, in the hardwood stands on the ridges, it was 10° F. Though timbered tracts afford considerable protection from wind and winter storm, the feeding slopes are even more favorable because of superiority in absorbing heat from the sun.

When on these concentration areas, the deer bed down during the day in any convenient cover (as in a clump of brush, under a scrubby tree, or in the lee of a rock), keeping together in bands of 15 or more. Although small, dense stands of young white pine, from a tenth to half an acre in extent are found on these slopes, the deer shun this cover during the resting period, resorting rather to the open mixed woods where the sun strikes through to the ground. When the spring thaws begin, the winter herds break up into progressively smaller bands and the deer return to their summer range.

Winter deer concentrations in central New York are in response to definite ecological factors—depth of snow and protection from wind. In years of heavy and persistent snow, deer gather early on favorable areas, move about but little, and return to their summer range only when the snow has melted. In seasons of light or intermittent snowfall, such as 1936–37, the tendency to congregate is much less marked and the deer may remain on their extended range practically throughout the winter.

It has generally been considered that the white-tailed deer is essentially a browsing animal (Clepper, 1931; Pearce, 1937; Cox, 1938; Cook, 1939; Hellmers, 1940; Aldous, 1941). Dixon (1934) states that, in California, the mule deer browse relatively more than they graze, although at certain seasons fresh green grass may form as much as 90 per cent of the food. On the basis of our observations on central New York wintering grounds, the white-tailed deer are *confirmed grazers.* They browse also, and in the woods and brush lots, they sample almost every species of tree and shrub. Occasionally a band will enter a patch of sumac and browse the twigs, many being eaten that are thicker than a pencil. The smaller, field-growing viburnums are extensively browsed, but, by and large, the deer during late winter and early spring are grazers,

very definitely preferring to forage on the meadowlands and hill pastures. They do not eat the dead and dry grass tops, but rather the succulent basal portions. Especially do they like to feed in orchards, where fallen apples are available in addition to grass.

Most meadows and orchards in this region are maintained in timothy, clover, or alfalfa. On the side-hill pastures the sod is often thin and much broken by heaving and slipping. Many fields are in poverty grass (*Danthonia*), and other areas are so depleted as to be clothed chiefly by weeds. In the grass lands the deer are especially partial to wild white clover (*Trifolium*), feeding avidly on the new shoots and exposed stolons. They are fond also of dandelion, orchard grass, fleabane (*Erigeron*), devil's paintbrush, alfalfa, evening primrose, and plantain. Great patches of winter wheat are often cropped close to the ground. Deer have also been noted eating such aromatic species as fragrant sumac (*Rhus*) and wild thyme (*Thymus*). In the wintering areas of central New York, opportunities for grazing are abundant and the deer remain in good condition, even though they eat but little browse.

These wintering areas are chosen because of topographic features and not for seclusion, so that conflicts with human interests seem to be unavoidable. Trouble is inevitable where certain land uses particularly susceptible to injury by deer are located on these wintering areas. Forest plantations, notably of pine, for which the deer appear to have a fondness, and nurseries and orchards may suffer severely.

With the reestablishment of the deer on the more fertile and favorable parts of their former range, some changes in habits are to be expected. Central New York differs from other sections of the Northeast in its topography, its climate, and in its land use pattern; the response of deer to the environmental factors differs accordingly. The data here presented offer a new insight into the wintering habits of the white-tailed deer—a glimpse heretofore unrecorded.

The writers have had opportunity to observe the return of the deer to the Allegany Plateau from the beginning. Both have had long and intimate acquaintance with several of the concentration areas and are familiar with the situation throughout the Plateau. Cook's contributions are based on data accumulated while a member of the CCC supervisory force. Opinions expressed herein do not necessarily reflect the opinion of the Conservation Department where he is now employed. Thanks are due to Supt. Earl D. Brockway of CCC Camp S-93, Breakabeen, New York, who has made available detailed knowledge of deer wintering in Schoharie County.

CONCLUSIONS

The deer in central New York are still increasing rapidly.

In winter they congregate on certain favorable south and southeast slopes that are protected from wind and where the sun keeps the snow at minimum depth.

The deer bed down in cover and graze in the open on succulent grasses and herbs.

Successful wintering in seasons of deep snow depends on the quality of the range in the very limited areas of suitable slope and exposure.

Concentrations are in response to topographic and climatic features that are unchangeable.

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IDENTIFICATION OF SEX IN LIVE MUSKRATS[1]

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One problem in the management and breeding of muskrats is the difficulty in determining the sex of the living animal. No valid criteria as to color or size exist, so it is necessary to examine the external genitalia and the region between the genitalia and anus. In the meager literature available on the subject a "sexing funnel" for holding the animal has been recommended by Hodgson (1930) and others (1929). When large numbers of animals must be examined such devices are usually difficult or impractical to use. This paper reports a simple method for examination that has been used successfully at the United States Fur Animal Field Station, Blackwater National Wildlife Refuge, Cambridge, Md.

The sex of an adult muskrat can be determined by palpation. The animal to be examined is picked up by the tail, then lowered until its front feet rest on some rough surface such as a board or table. If held in this position for a few moments it usually calms down. The sex can then be accurately determined by external manipulation with the fingers (Pl. 25A). Extreme caution is recommended for the muskrat is very quick and agile and will attempt to turn and bite.

A protuberance or urinary sheath is present in both sexes in muskrats. This lies in the ventral mid-line anterior to the anus (Pl. 25, B, 1, 2 and 3); it represents the sheath covering the penis in the male and the anterior rim of the introitus (vaginal entrance) in the female. The relatively long and solid penis of the adult male can be felt within the sheath or the prepuce can be pushed back so as to uncover the penis. The protuberance of the male is long and somewhat rounded, but the corresponding structure of the female is less conspicuous, more pointed, and comparatively short. The vaginal opening is often difficult to see in nonbreeding females for it may be covered by a vaginal closure membrane but it is prominent in adult females during the breeding season.

Determination of the sex of the newborn muskrat and of those up to three weeks of age is rather difficult but can be done with a fair degree of certainty. The greatest difficulty is encountered with animals from three weeks to six months of age. The most convenient criteria in determining the sex of such animals are the distance between the anus and the protuberance and the presence or absence of hair over a portion of this area, known as the perineum. In the male the perineum is longer and is covered with hair; in the female it is short and the anterior portion is hairless. This bare area is small but nevertheless definite. This difference exists in the adult as well as in the immature muskrats and offers, therefore, an easy method of determining sex.

[1] Special acknowledgment is given Robert K. Enders of Swarthmore College for valuable suggestions in the preparation of this paper, and to Eleanor M. Paxson for the line drawings.

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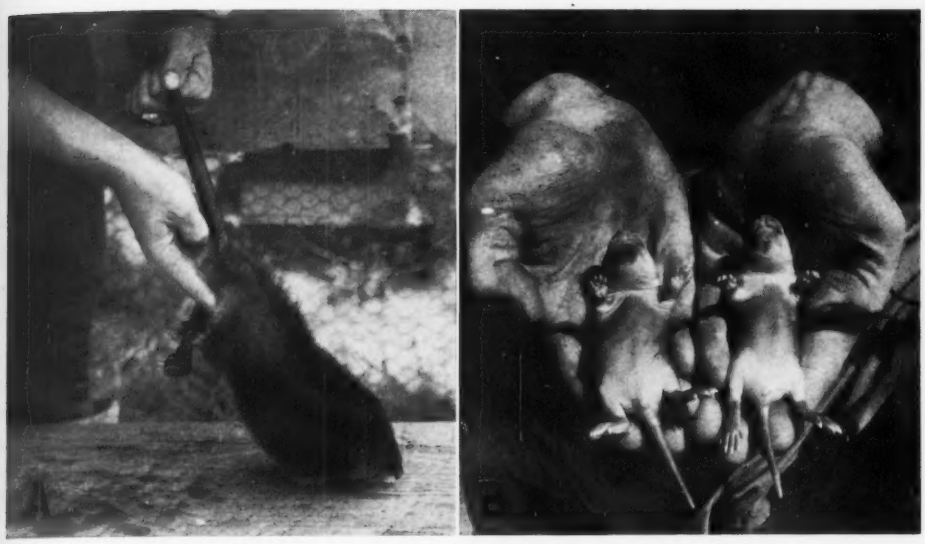
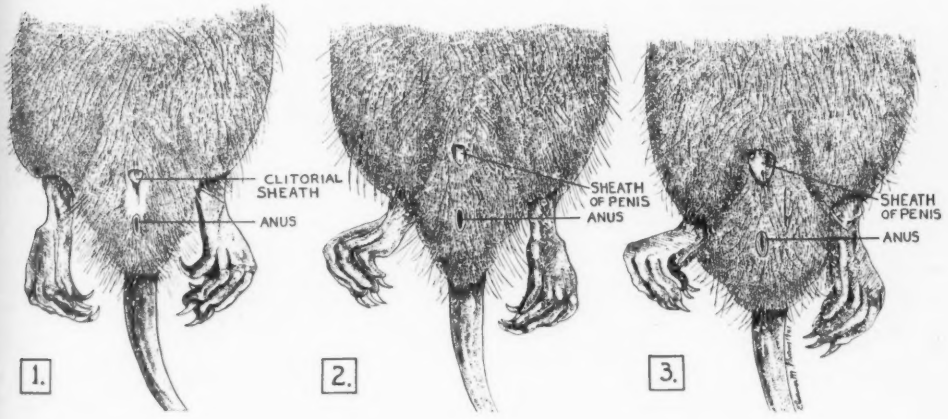
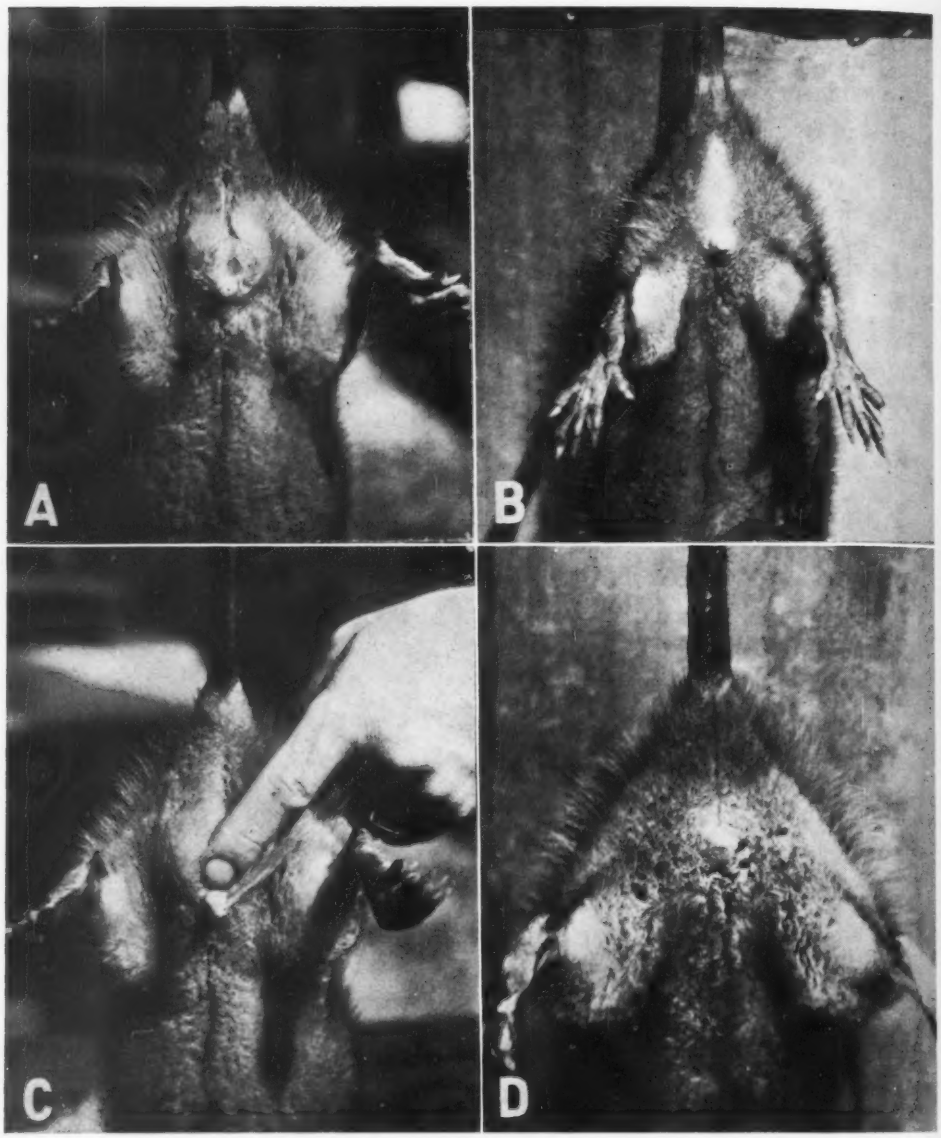


A. Position for examining muskrat to determine sex. *B*. Male and female about one week old. *Below*. Genitalia and anus of female (1), young male (2), and mature male (3).





A. Male muskrat, testes in breeding condition. *B.* Male, external genitalia. *C.* Male, penis extruded by pressure of finger. *D.* Female, external genitalia.

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ANONYM

A study of the photographs and drawing will be profitable before attempting to sex the muskrats.

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COLOR, SEX RATIOS, AND WEIGHTS OF MARYLAND MUSKRATS

Herbert L. Dozier and Robert W. Allen

The race of muskrats known as the Virginia muskrat (*Ondatra zibethica macrodon*) inhabits the Middle Atlantic States from Delaware Bay to Pamlico Sound, North Carolina. Two color phases occur commonly throughout its range, a black and a brown, the latter being more abundant. These are described by Hollister (1911), who states that in some localities the black phase exceeds the brown in numbers. Le Compte (1934) asserts that the population of some Maryland marshes runs as high as 60 to 65 per cent black, but does not give the source of his information. Harris (1937) gives figures on muskrat production on southern New Jersey marshes, presents a price chart based on a yield of 20 to 25 per cent black, and states that higher prices are normally paid for black pelts.

During recent years much attention has been given to the relative abundance of these color phases by the staff of the U. S. Fur Animal Field Station, Blackwater National Wildlife Refuge. This reservation, on the Blackwater River in Dorchester County, Maryland, is representative of some of the best muskrat marsh in that state. Advantage was taken of controlled trapping operations during the winter of 1941 (January 1 to March 15) to obtain as complete data as possible on the yield of 9,895 muskrats. Each animal was carefully examined by one or both of the writers. The color phases are subject to considerable variation, but little difficulty was experienced in classifying adults as either brown or black. Classification of the "kits" or young was slightly more difficult.

To control properly the trapping of the muskrats, the refuge was divided into 27 "hunts" or units and separate records kept for each. Table 1 records the catch, and the representations of the color phases and sexes for each unit. Considerable local variation is evident in the proportion of black and brown individuals, even on adjoining units.

TABLE 1

ADULT MUSKRATS TRAPPED ON THE BACKWATER NATIONAL WILDLIFE REFUGE, 1941

Unit No.	*Total Catch*	*Percentages*			
		Color		*Sex*	
		Black	*Brown*	*Males*	*Females*
1	288	42	58	54	46
2	269	52	48	57	43
3	203	59	41	53	47
4	481	49	51	53	47
5	362	54	46	56	44
6	394	57	43	56	44
7	243	55	45	56	44
8	292	61	39	54	46
9	313	54	46	60	40
10	603	49	51	54	46
11	164	54	46	60	40
12	242	55	45	60	40
13	167	67	33	58	42
14	427	56	44	52	48
15	644	47	53	57	43
16	567	51	49	61	39
17	512	43	57	55	45
18	367	57	43	55	45
19	542	57	43	70	30
20	211	56	44	57	43
21	215	57	43	61	39
22	381	58	42	56	44
23	318	50	50	57	43
24	701	66	34	53	47
25	447	57	43	56	44
26	349	58	42	58	42
27	193	44	56	54	46
	9,895	53.6	46.4	56	44

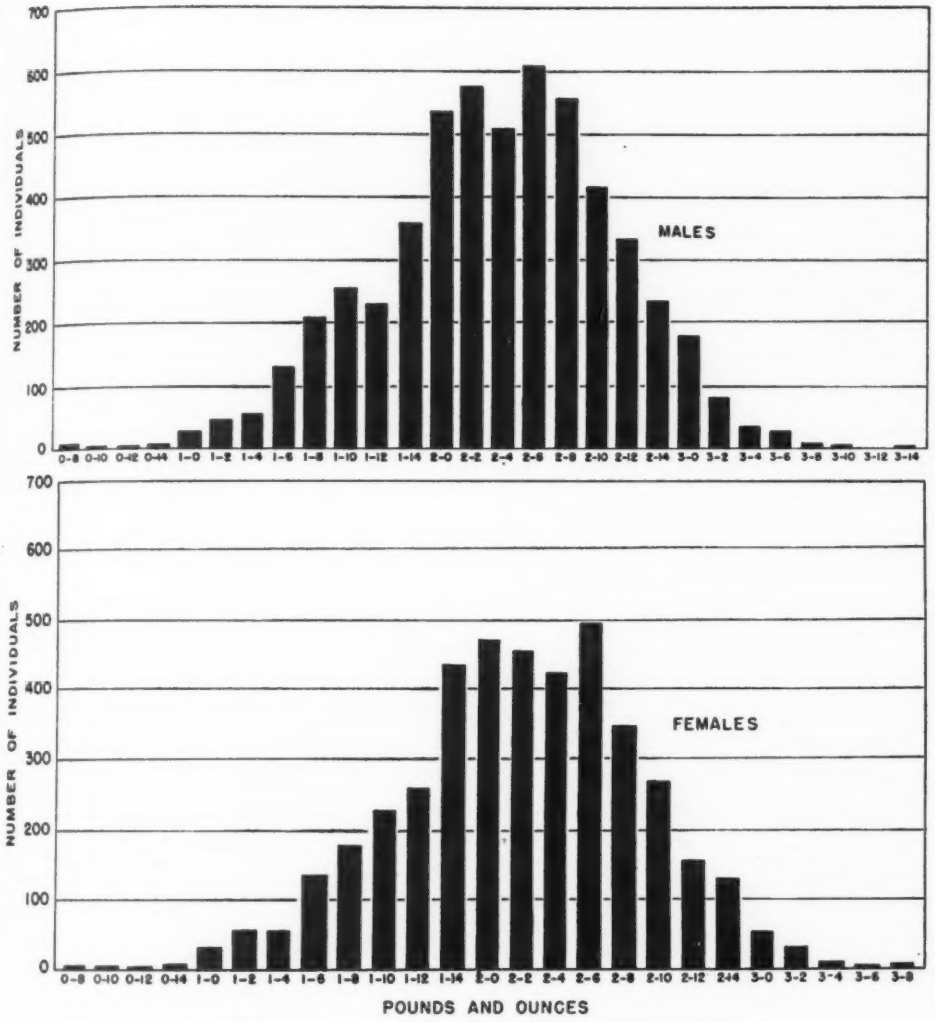

Fig. 1. Distribution, by weight, of Maryland muskrats.

The highest ratio was found on Unit 13 which had 67 black to 33 brown animals and the lowest on Unit 1, with a ratio of 42 to 58. The total catch comprised 5,304 black and 4,591 brown animals, or 53.6 to 46.4 per cent.

SEX RATIO

Considerable information is available on the sex ratio in muskrats, but most of it is based on rather small series. The records all have been obtained from wild animals trapped during the legal open season, except in the report by Smith (1938) on 52 pen-reared muskrats in Maryland during 1931 and 1932 that were equally males and females.

The data (Table 2) show a clear preponderance of males over females. Of

TABLE 2

RECORDED SEX RATIOS OF MUSKRATS

Locality	Race	Number sexed	Trapping season	Percentages		Authority
				Males	Females	
Louisiana	*rivalicius*	600	1925–26	47	53	Svihla
Louisiana	*rivalicius*	263	1926–27	67	33	Svihla
Utah	*osoyoosensis*	1,556	1936–37	51.9	48.1	Marshall
Delaware	*macrodon*	2,778	1938–39	60.6	39.4	Stearns & Goodwin
Maryland (Dorchester Co.)	*macrodon*	258	1933 1936–38	64	35	Smith
Maryland (Worcester Co.)	*macrodon*	1,584	1926–32	56	43	Smith
Minnesota	*zibethicus*	491	1938	57.2	42.8	Hatfield
Wisconsin	*zibethicus*	2,287	1939–40	68.9	31.1	Buss
Iowa (young)	*zibethicus*	878	1934–36	54.4	45.6	Errington
Iowa (fall-trapped)	*zibethicus*	584	1936–38	54.9	45.1	Errington
Illinois	*zibethicus*	500	1940	58.8	41.2	Frison *et al.*
Vermont	*zibethicus*	1,294	1940	65.4	34.6	Seamans
Pennsylvania	*zibethicus*	335	1938–40	58.8	41.2	Grimm
Pennsylvania	*zibethicus*	675	1940	58.7	41.7	Grimm
England	*zibethicus*	1,330	1933 & 1934	56.9	43.1	Warwick

TABLE 3

AVERAGE WEIGHTS (IN POUNDS) OF MUSKRATS CAUGHT ON THE BLACKWATER NATIONAL WILDLIFE REFUGE BY TRAPPING UNITS, 1941

Unit No.	Brown		Black		All
	Males	Females	Males	Females	Individuals
1	2.37	2.26	2.64	2.22	2.38
2	2.40	2.29	2.46	2.31	2.38
3	2.27	2.14	2.49	2.27	2.31
4	2.37	2.34	2.44	2.40	2.39
5	2.33	2.36	2.48	2.25	2.36
6	2.30	2.16	2.38	2.12	2.26
7	2.33	2.29	2.38	2.21	2.31
8	2.19	2.12	2.05	2.23	2.12
9	2.16	2.16	2.15	2.15	2.15
10	2.22	2.08	2.30	2.13	2.19
11	2.18	2.15	2.15	2.09	2.15
12	2.23	2.06	2.37	2.20	2.23
13	2.17	2.04	2.18	2.18	2.16
14	2.29	2.16	2.23	2.14	2.18
15	2.19	2.03	2.23	2.07	2.14
16	2.43	2.29	2.46	2.29	2.37
17	2.17	2.00	2.23	2.10	2.13
18	2.06	1.92	2.06	1.96	2.01
19	2.24	2.07	2.16	2.06	2.13
20	2.27	2.22	2.42	2.21	2.30
21	2.41	2.22	2.36	2.24	2.32
22	2.41	2.10	2.41	2.17	2.21
23	2.34	2.43	2.40	2.21	2.36
24	2.39	2.12	2.41	2.48	2.37
25	2.26	2.21	2.29	2.18	2.24
26	2.27	2.09	2.18	2.18	2.19
27	2.41	2.27	2.55	2.37	2.40

the 9,895 muskrats trapped on the Blackwater Refuge in 1941, 9,304 adults were sexed. There were 5,210 (56%) males and 4,094 (44%) females.

Trappers in New York reported to Johnson (1925) that at the latter part of the season the male muskrats hide but the females wander about and are more easily caught. In Utah Marshall (1937) found that more males were trapped in the fall and fewer in the spring. His trapper stated that "the first few nights of a set usually yield males rather than females." Local trappers in Maryland also report that early in the season more males are usually caught than females and that the reverse is true in the last weeks of the season. Our observations for several seasons tend to support this generalization but it was not so in the 1941 season. Quite possibly the greater wandering tendencies of males results in more of them being caught during the earlier trapping operations.

Errington examined 86 new-born young in their nests and found 58.1 per cent of males. Of 878 young less than two weeks old, 54.4 per cent were males and 45.6 per cent were females. The adult sex ratio may not be the same as that at birth, because the sex ratio in 450 kits trapped on the Blackwater Refuge in 1941, and very carefully sexed, was 45.8 per cent of males to 54.2 per cent of females.

WEIGHTS

Surprisingly little information is available on the average weights of muskrats. Weights of adequate series would be of considerable aid in evaluating the validity and status of the various races and subspecies.

Schoonmaker (1920) gives the average of 11 from New York as 2.34 pounds; one female weighed 3 pounds 8 ounces. Grinnell *et al.* (1937) in discussing the Colorado River muskrat (*Ondatra z. bernardi*) in California gave the average of 14 males as 658.4 grams, and of 5 females as 557.7 grams, a general average for the 19 of 629.6 grams; six males of the Nevada muskrat (*Ondatra z. mergens*) averaged 984 grams.

Errington (1939) gave the average weight of 34 muskrats, (*Ondatra z. zibethicus*) taken in northwestern Iowa during November and December as 1,092 grams (2.41 pounds) and 10 summer specimens from the same locality averaged 1,132 grams (2.49 pounds). The largest individual was an adult male, taken in summer, and weighed 1,586 grams (3.49 pounds). Frison *et al.* (1941), for the same race in Illinois, state that "cursory inspection of weight data indicates that most adult muskrats weighed between 2.50 and 2.75 pounds." Grimm (1941) gives weights of 547 muskrats (*Ondatra z. zibethica*) trapped in northwestern Pennsylvania during December and January; males averaged 2.47 pounds, and females 2.26 pounds. In Delaware Stearns and Goodwin (1941) found an average weight of 2 pounds for 2,278 trapped muskrats; the maximum was $2\frac{3}{4}$ pounds. Buss (1941) gives the average of 352 males, trapped in Wisconsin, as 1015.9 grams and that of 237 females as 1057.9 grams. Seamans (1941), at Lake Champlain, Vermont, obtained an average for 94 males of 2.77 pounds and for 56 females of 2.46 pounds, or 2.66 pounds for the 150 individuals.

Weights were obtained for all animals trapped on the Blackwater Refuge, during 1941, but those of any partly eaten by predatory or scavenger birds or mammals while in the traps were discarded. Weights of the remaining 9,754 are summarized in Table 3.

The weighing was done with a Chatillon hand-scale reading in pounds and ounces. Most of the animals were weighed within 24 hours after being caught, but a few remained frozen in the traps for several days before being weighed. They were weighed as soon as possible after being brought in from the trap-lines and were usually slightly damp. Some were wet but as only a small number were wet enough to affect the weight and these were scattered about equally among the different sex and color groups, it is believed that they made no significant difference in the results.

The muskrats varied in weight from 6 ounces to 3 pounds 14 ounces. Only 21 animals weighed more than 3

pounds 6 ounces, and 16 of these were males. The muskrats were divided for grading into two groups; all weighing 1 pound 6 ounces or less were classed as "kits" and those weighing more were considered adults.

The 9,311 adults averaged 2.25 pounds (1,020.5 grams) in weight. There were decided differences in weight between the sexes, males averaging heavier than the females. The 2,462 brown males averaged 2.29 pounds (1,038.7 grams) and 1,895 brown females, 2.16 pounds (979.6 grams), as against an average of 2.32 pounds (1,052.3 grams) for 2,795 black males, and 2.21 pounds (1,002.4 grams) for 2,159 black females. The average for all adult females was 2.19 pounds (983.3 grams) and for all adult males 2.30 pounds (1,043.2 grams). The brown animals, including both sexes, averaged 2.23 pounds (1,011.5 grams) and the black 2.27 pounds (1,029.6 grams).

Table 3 gives the average weights by sex and color groups from the different units. In almost every group, the males averaged heavier than the females. Muskrats from the various units varied considerably in average weight. Some of the variations are rather difficult to account for but most of the low weights were recorded from areas poorly supplied with food plants. During November and December, preceding the trapping season, the number of muskrat houses on each unit of the refuge was counted and notes were taken on the character and abundance of the muskrat food plants present. All units reported as poor in the abundance and quality of food plants yielded muskrats below the average weight for the refuge, and the poorest unit the animals lightest in weight. Mite infestation was extremely low during the 1941 trapping season and could not have been responsible for any decided decrease in the average weight. No correlation between weight and density of population could be found; some units with high populations had light weight animals whereas others with high populations had heavy animals. No appreciable change in average weight was noted as the trapping season progressed.

Figure 1 shows the distribution of the muskrats trapped by 2-ounce weight groups. In both males and females many weighed from 2 pounds to 2 pounds 2 ounces, and in both sexes, the largest number of individuals weighed 2 pounds 6 ounces. Since the population sampled consisted of adults and of those young born in the spring and summer preceding the trapping season, it seems quite possible that the lower peak of the graph represents the younger animals and the higher peak the older muskrats. There is, of course, overlapping between these groups but the indications are that approximately half the animals were born the preceding season.

SUMMARY AND CONCLUSIONS

Data are given on the 1941 catch of 9,895 muskrats (*Ondatra z. macrodon*) on the Blackwater National Wildlife Refuge. Of the total, 53.6 per cent were of the black color phase and 46.4 per cent brown. Variations from this percentage occurred on the 27 trapping units of the Refuge, even on adjoining areas, ranging from 42 black to 58 brown to as high as 67 black to 33 brown.

Of the total catch, 9,304 were considered to be adults; these comprised 5,210 males (56%) and 4,094 females (44%). Of muskrats weighing less than 1 pound 6 ounces 450 were classified as "kits"; they included 206 males (45.8%) and 244 females (54.2%). Trapped muskrats may not be truly representative of sex distribution on the marsh because of the greater wandering tendencies of males.

Average weights were obtained for 9,311 adults. Brown animals, of both sexes, averaged 2.23 pounds (1,011.5 grams) and the black 2.27 pounds (1,029.6 grams). Decided differences were noted between the sexes, the males averaging heavier than females. The 2,462 brown males averaged 2.29 pounds (1,038.7 grams), and 1,895 brown females 2.16 pounds (979.6 grams) as against an average of 2.32 pounds (1,052.3 grams) for 2,795 black males and 2.21 pounds (1,002.4 grams for 2,159 black females.

Many of both sexes weighed 2 pounds to 2 pounds 2 ounces; these are believed to be young animals. The 2 pound 6 ounce group contained the largest number of individuals, thought to be adults more than a year old.

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MUSKRATS ON THE TEXAS COAST

Daniel W. Lay and Ted O'Neil

Approximately 260,000 acres of marshland on the southeastern Texas coast between Galveston Bay and Louisiana (Fig. 1) yield an annual crop of muskrat pelts which in at least one recent season (1939–40) exceeded 350,000. This marsh area is the westernmost range of the Louisiana muskrat (*Ondatra zibethica rivalicia*). The soils and plants of Texas marshes are fairly comparable with those of southwestern Louisiana, although problems of management vary greatly from marsh to marsh.

The observations here reported were made between June, 1938 and May, 1941. Lay made occasional trips to the various marsh areas during the entire period, and O'Neil devoted almost full time to the work between September, 1940 and February, 1941, when with the Texas Game, Fish and Oyster Commission.

General Characteristics of the Marshes

The method of formation of the Texas marshes varies somewhat but generally the process has been one of subsidence according to W. Armstrong Price (letter, March 26, 1940). One important characteristic is that almost all the marsh area lies behind beach ridges of sufficient size to prevent direct influx of seawater except when hurricane winds blow directly inshore. The marshes overlie a heavy mineral soil and the peaty layer is often only a few inches thick. The formation of peat is apparently limited by the frequent droughts which allow rapid oxidation of plant remains. Hurricanes occasionally strike the coast and force salt water either directly over the shore ridges or through high tides and have considerable influence on muskrat populations.

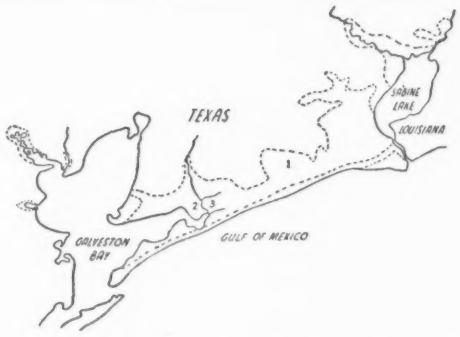

Fig. 1. Location of muskrat marshes and study areas in Texas: 1. Pipkin-DeMary; 2. James Jackson; 3. Hugh Jackson.

The general topography is level. There are about 20 lakes with an average size approaching 500 acres. An intracoastal canal, two rivers and many bayous drain the marshes.

The mean annual rainfall at Port Arthur is 51.81 inches, extremes from 1911 to 1930 being 66.07 and 30.52 inches. The mean annual temperature is 68.9°F., with an average of only six days a year when the minimum is below freezing.

Penfound and Hathaway (1938) have discussed thoroughly the plant communities of southeastern Louisiana and their major classifications apply to the Texas marshes. In the saline portions (Spartina alterniflora Consocies) salt cane (*Spartina alterniflora*) is the pio-

neer species bordering tidal inlets and lagoons; saltgrass (*Distichlis spicata*) is the only other common species there. The honey-mangrove community (Avicennia Consocies) described by Penfound and Hathaway is represented by a few scattered plants of honey-mangrove (*Avicennia nitida*). The brackish marshes (Spartina-Distichlis-Juncus Associes), the most productive of muskrats, are marked by smooth cordgrass (*Spartina patens*), saltgrass, black rush (*Juncus romerianus*), bayonet rush (*Scirpus olneyi*), and three-cornered rush (*Scirpus robustus*). The cane zone (Phragmites-Spartina cynosuroides Associes) occurs in slightly less brackish sites and apparently on more mineralized soils. It is characterized by roseau (*Phragmites communis*) and quill cane (*Spartina cynosuroides*), frequently interspersed with plants typical of the brackish and the fresh marshes. The fresh marsh (Typha-Scirpus Associes) includes cattail (*Typha angustifolia* and *T. latifolia*), giant bulrush (*Scirpus californicus*), squarestem spikerush (*Eleochris quadrangulata*), duck potatoes (*Sagittaria* spp.) and various associated species. In slightly brackish sites with abundant water, there are almost pure stands of sawgrass (*Cladium jamaicensis*) which might be considered a Cladium Consocies.

Smooth or saltmeadow cordgrass and saltgrass are the dominant species on the brackish and saline marshes. These marsh species form roughs which exclude almost all bayonet and three-cornered rushes and other important muskrat food plants when an area goes unburned for more than two years, or is subjected to dry periods or unusually salty tides. The cordgrass in the brackish marsh produces much of the humus on the marsh floor. In deep water this species has been observed by John J. Lynch to form roots at each node and thus elevate itself above the water level. It is highly desirable as a lodge-building material for muskrats, but must be checked enough to prevent exclusion of the important muskrat food plants.

The three principal study areas represented fresh to slightly brackish, brackish, and brackish to saline conditions; they are described below, with the management experience gained from each.

FRESH TO SLIGHTLY BRACKISH MARSH (DEMARY-PIPKIN)

The Pipkin Big Hill marsh in south-central Jefferson County is leased and managed for muskrats by Joe DeMary. It is of 15,000 acres, fresh to slightly brackish, and relatively deep, and lies between the intracoastal canal and the rice fields and prairie; about 6,400 acres are under intensive muskrat management. The marsh receives fresh water drainage irregularly from a large area but no tides, although it was affected earlier by brackish tides through a long chain of lakes emptying into Sabine Lake. The principal stream in the marsh is known as Salt Bayou, and the presence of scattered roots of three-cornered rush substantiates reports that formerly the marsh was of the meadow-type characteristic of the brackish community. Now it is dominated by sawgrass, bulrush, and roseau cane, some to 18 feet in height, that shades out lower vegetation. Sawgrass occurs in almost pure stands in the deeper water and also at abandoned alligator holes. At the margins where the water is shallower

and drought first occurs the plants are cutgrass (*Leersia oryzoides*), maiden cane (*Panicum hemitomon*), water primrose (*Jussiaea* sp.), pickerelweed (*Pontederia* sp.), white waterlily (*Castalia* sp.), and square-stem spikerush. More brackish sites, not in deep water, have the typical Spartina-Distichlis-Juncus Associes, but this community is of limited extent.

The marsh is part of a cattle ranch. During the winter cattle work in so far as the depth of the water and secure footing will permit, but in summer they prefer the prairies most distant from the marsh which are freer from insect pests. They rarely get into the cane and sawgrass but concentrate on the meadow-like marshes of smooth cordgrass and associated plants and on all edges of the marsh.

History. Two events contributed to changing this marsh from a brackish meadow-type to the present fresh deep marsh. A drought in the late summer and autumn of 1924, the most severe ever recorded by the Weather Bureau at Port Arthur, was followed by a peat fire that burned deep into the marsh to leave many openings which later filled with water. Then in 1933 the intracoastal canal was constructed, and the natural drainage system was altered so that no brackish tidal waters could reach the marsh. This hastened the invasion of the fresh water marsh community in the peat burns. The rice field drainage was held behind the intracoastal canal levee slowly draining through the single set of locks at Salt Bayou. Because the runoff from rains and rice field drainage were irregular, the natural bayous in the marsh could not maintain their distinct channels after tidal action was stopped by the canal. With the resultant fresh water, aquatic vegetation invaded the channels and completely clogged all but the major ponds and bayous. By 1938, when management work began, the marsh growth had so occupied the bayous that the marsh was almost continuous, with several prairie streams emptying into it and one short bayou draining out to the intracoastal canal. When rains or rice field drainage brought a heavy inflow, the water level rose several feet because of the slow drainage through dense cane and sawgrass. The extremes of water level are a major factor affecting muskrat populations on the marsh.

Trial Management Efforts. When Joe DeMary began operations in 1937, he constructed a marsh tractor of his own design, using a Buick motor, a power winch, and special frame and wheels (Pl. 27, *A*). The rear wheels were 6 feet in diameter with cleats 4 feet long, and the front 3½ feet with 26-inch cleats. A chain and sprocket geared down the speed to compensate for the enlarged wheel diameter. Vehicles of this type will not operate successfully in delta and sub-delta soft peat and floating marshes. An observation tower was rigged to enable a "pilot" to ride 15 feet above the driver and direct him when operating in the cane. The first cruising of the marsh in the autumn of 1937 disclosed vast areas where cane and sawgrass were so dense that the vegetation entirely supported the weight of the tractor which had to be bucked through.

Burning. Immediately after the 1937–38 trapping season much of the rough was burned (for the first time in five years) to remove most of the tops of

cane and sawgrass. This opened the stand enough for some understory increases of cattail, smooth cordgrass and three-cornered rush. By the winter of 1938–39, recovery was insufficient for a second burn. The cane and sawgrass must be well matted and dry to burn satisfactorily. After the third trapping season, another good burn was made in the sawgrass and cane; this resulted in further increase of the more desirable cattail and three-cornered rush. With progressive thinning of the tall vegetation there was an increase in density of shorter meadow-type vegetation which will eventually produce enough annual growth to burn each year and thus further check the edaphic climax and undesirable sawgrass and cane. There are indications that early spring burning of the undesirable rough is bringing an increase in muskrat habitat. The soil is not brackish enough to produce typical brackish plant communities, but cattail and some three-cornered rush and smooth cordgrass are increasing. With the existing bulrush, the marsh should support increasing numbers of muskrats.

Ditching. Because of fluctuations in water levels and the difficulty of foot travel for trappers, 85 miles of ditches were constructed, (Pl. 27, *C*, *D*). A special giant turn plow was used behind the marsh tractor, being pulled with the winch while the tractor wheels were anchored. A cable 300 feet in length was used and the tractor was moved forward after each pull. Three men rode the plow, which operates best in a few inches of water, to keep the beam level and to keep vegetation from clogging the share. Through the center of the marsh are 9 miles of double ditch as a direct drainage channel for excess water. This was made by plowing two ways and throwing a levee on each side; it is 20 to 40 inches deep and 4 feet wide. The single ditches are 15 to 24 inches deep and 30 to 40 inches wide. Levees are about 18 inches high when settled. Double ditches cost about 35 dollars per mile.

The ditches are not continuous. During dry periods they merely hold water, but with an excess of water in the marsh they accelerate drainage. They are used as pirogue trails by the trappers who can cover 7 to 8 miles of marsh a day by boat, where they could cover only 1 to 3 miles afoot. Muskrats use the levees as feeding and resting places and for foundations for their houses. Raccoons, minks, and otters use the levees as travel lanes and otters make slides on them. The levees also are ideal sites for placing traps, especially when the trapper is traveling in a pirogue. The ditches and the marsh tractor trails serve as fire lanes and make controlled and staggered burning possible.

Muskrat Populations. This marsh yielded several thousand muskrat pelts the year before the 1924 drought, when its decline began. The catch in 1937–38 was 470 pelts of poor quality, and represents the production of an unmanaged marsh, as burning and ditching began in the spring of 1938. The 1938 catch was 2,892 muskrats of better quality; this increased catch seems to have resulted from the burning. The 1939–40 catch was 6,614 pelts, showing continued improvement. The 1940–41 crop dropped to 1,750 muskrats after preseason estimates placed the probable crop at 12,000 or more. The apparent cause for the curtailed

catch was excessive flood water impounded on the area during repairs of the spillway gate at Salt Bayou on the intracoastal canal. Water levels were raised 17 inches three days after the repairs began, covered all levees and many muskrat houses, and forced the muskrats off the area.

Counts of muskrat beds or lodges made along the ditches in May 1939 gave an average of 0.8 beds per acre on 43.6 acres. Most of the beds were found in smooth cordgrass and bayonet-rush brackish marshes; no counts were made in the deep sawgrass community. During the winter of 1940, an average of 0.78 beds per acre were counted on 98 acres. The difference is not significant; and some of the census strips were located in sawgrass. The beds were fairly well distributed among different plant communities except the sawgrass. Estimates of the number of adult or subadult muskrats to a bed varied from four to six.

Material for lodge construction is more available in the meadow-like areas of smooth cordgrass, but these occur near ridges or edges of the marsh where predation by minks and raccoons is more serious. In the deeper marsh, beds are constructed of the coarser bulrush and cane, and apparently are less vulnerable to predation. Of ten beds in cordgrass near ridges examined January 21, 1941, eight had been bored by minks or raccoons. The openings in the tops or sides of the beds were small neat holes typical of mink depredations. Several owl pellets containing remains of young muskrats were found on two of the bored houses. Cottonmouth moccasins (*Agkistrodon piscivorus*) are more numerous here than in any other Texas marsh but their relation to muskrats has not been determined.

Droughts affect this marsh less than those south of the intracoastal canal, and part of the good fall population in 1940 probably was made up of muskrats that had been attracted by the water in the ditches and alligator holes; yet this advantage of the marsh is partly nullified by the heavy rains usual before December.

The alligators (*Alligator mississippiensis*) on this marsh serve muskrat management in at least two ways. Their holes retain fresh water in dry periods, and the movements of alligators in the pools prevents stagnation of the water. There are muskrat beds close to almost every alligator hole, indicating the attractiveness of these pools to muskrats. The predation of alligators on muskrats is a controversial question, but here the alligators apparently do more good by improving the habitat than harm by possible predation. A second benefit is the scouring of ditches, along which the alligators travel and thereby reduce clogging by vegetation and obstructions. The alligators are increasing under protection by DeMary, who has overcome the typical prejudice against the species as a predator of muskrats, but the population is far below that in 1924 when Joe Billiard reportedly killed 97 in one night.

Discussion. In the fresh to slightly brackish marsh severe burning of the roughs of sawgrass and cane under certain conditions thins these species and permits the increase of plants more desirable as food and house materials for muskrats. Late winter is probably the optimum time for such burning.

Ditching has proved beneficial in draining excess water, holding small amounts of open water during droughts, and facilitating travel and trapping. The ditch levees also serve as travel lanes for muskrats, minks, raccoons and otters and are especially useful when water is deep in the marsh.

The process of changing the present mostly fresh marsh of cane, sawgrass, bulrush, and cattail to a more typical brackish marsh attractive to muskrats is progressing under the burning management; but complete success may be prevented by lack of salt water. The marsh also is used somewhat as a rice irrigation reservoir, prohibiting the induction of salt water from the intracoastal canal.

BRACKISH MARSH (JAMES JACKSON)

The James Jackson marsh of about 16,900 acres, is part of a cattle ranch in Chambers County west of Oyster Bayou and north of East Galveston Bay. The marsh is over a tight clay subsoil and is of relatively high salinity. High tides occasionally invade it and droughts seriously limit its surface water supply. There are no deep peaty soils, and no fresh water enters the marsh. The average annual rainfall is somewhat under 50 inches.

The vegetation is typical of salt marsh meadows, smooth cordgrass predominates, with bayonet and three-cornered rushes, saltgrass, and some black rush. Clump cordgrass (*Spartina spartina*) lines the borders. The bayous are lined with cane, probably because of protection from fire.

Hurricanes from the south or west cover the marsh with destructive waves of sea water, and those from the southeast or east come overland. Any hurricane causes high tides that back salt water over much of the marsh.

History. Trapping was secondary to grazing before 1938 when James Jackson undertook management of the muskrat resource. Previously range cattle had grazed on the prairies in summer and on the marshes in winter. In the occasional years when there were good populations of muskrats, the trapping was leased on a temporary basis which produced no incentive for preserving either the breeding stock or the marsh habitat. The 1915 hurricane covered much of the prairie as well as the marsh. There are some reports that no muskrats occurred previous to that time, but Audubon in 1824 (Geiser, 1930, p. 123) reported muskrats on Galveston Island, only 25 miles southwest. The muskrats were little noticed until after the last war; their commercial value then became sufficient to justify trapping.

Burning. As a management effort for winter grazing, cattlemen have customarily burned this marsh each September or October so there would be young greens available in late fall and winter. This has limited the cover and building material for muskrats in autumn when they begin preparing for colder weather. A modification of this system was used with some improvement for muskrats by burning in July when water protected the roots of the marsh plants. Dry weather after a summer burn has limited the growth recovery so that there is not enough cover for the winter.

The water temperature rises markedly after burning, with an increase in bacterial activity, and evaporation

A.
grade
marsh

A. DeMary marsh tractor. *B*. Levee on James Jackson low prairie constructed with road grader. *C*. Ditching with marsh plow and power winch. *D*. Completed ditch through cane marsh.

A. Electric fence with graded levee at each side for control of grazing, fire, and water; James Jackson marsh.
B. Pond formed by storm washout of marsh area "eaten out" by geese or muskrats.

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of surface water is also more rapid. A dry burn in August 1937 on the lower part of this marsh was followed by a rainless autumn, and the winter rains converted the area into an open lake (statement of H. C. Hillebrant). Muskrats did not reoccupy the burned area until the winter of 1938. In 1940 a trial of staggered burning was begun, alternate strips separated by ditches being burned in July. Each strip is burned every other year, so that muskrats will never be far from both succulent young growth and mature cover and house-building material. Complete protection from burning was tried for three years on 2,000 acres, but muskrats did not increase; hence the rough was burned in March 1941. After the second year of protection the saltmeadow cordgrass became so dense that under parts of the plants molded and disintegrated, the tops became so matted that a person could walk on them, and the more desirable bayonet and three-cornered rushes were crowded out. Aside from their effects upon muskrats unburned roughs are impracticable because of the difficulty for the trapper of walking in them.

Levees and Dams. Fluctuations in the water supply are extreme, and primary consideration has been given to conservation of water. All outlets into Oyster Bayou on the east have been dammed by use of a dragline; in some cases the dams were reinforced with piling. These dams serve to prevent drainage of the marsh. The natural levee on the bay shore and on the bayou edge are so low, however, that the dams are effective only at low water levels; during heavy rains or high tides water flows over the ridges.

During the very dry summer of 1940 a system of levees 16 miles in length (Pl. 27, *B*) was constructed in the drier marsh on the edge of the prairie, and about 4,000 acres of adjoining low prairie was enclosed in levees to make a new marsh. A crawler-type tractor and road grader were used, the heavy equipment being successful in the marsh because of the heavy clay subsoil close to the surface.

The rains were timely and early in 1941 there was a distinct increase of three-cornered rushes and smooth or saltmeadow cordgrass in proportion to the saltgrass and clump cordgrass. New muskrat beds appeared in the impounded marsh by early winter. The full results of this effort to make new marsh on low prairie will not be known for several years; an obvious problem is to produce a layer of peat on top of the prairie clay which is unattractive to muskrats for burrowing. It is already apparent, however, that plant succession is rapid after the impounding of water. The levee ditches are being improved to serve as irrigation channels for surplus water on rice on the adjoining prairie to further stabilize the water supply.

Exclusion of Cattle. Seven miles of electric fence are in operation along the outside levees to exclude cattle from the muskrat marsh, local trappers having convinced the landowners that damage to muskrat beds and runways justifies the fence (Pl. 28, *A*).

Muskrat Populations. Trappers reported a peak population in 1922. The drought in 1924 wiped out most of the animals, and their numbers were small thereafter on the western side of Oyster Bayou; under Jackson's management

the population is again increasing. Records of recent catches are: 1936, 11,000; 1937, 8,000; 1938, 8,000; 1939, 11,264; and 1940, 6,725. The catch for the winter of 1940 was lower because of a local drought between March and October when the marshes became waterless and many muskrats moved across Oyster Bayou to the Barrow marshes which were well watered. The lessened catch does not have any relation to the management program of dikes and levees during that summer as these areas did not receive water until late fall and were not trapped.

Discussion. Muskrats are now receiving the interested attention of landowners who previously used the marshes primarily for cattle grazing. The James Jackson project applies to brackish marsh with a shallow peat covering over heavy clay soil where water levels fluctuate considerably. The management trials in progress demonstrate the possibilities of making muskrat marsh from low prairies by impounding water with levees. Muskrat foods and muskrats increased the first winter on the trial areas.

BRACKISH TO SALINE MARSH (HUGH JACKSON)

This 4,600-acre marsh is across the lower part of Oyster Bayou from the James Jackson marsh. The soil is heavy clay overlaid with varying amounts of peat. Tides and rainfall are the only sources of water. The soil is more saline because of the more regular influx of brackish tides through Oyster Bayou on the west and Onion Bayou on the north. South of the tract is Mud Bayou and the intracoastal canal, but there is little drainage into them due to the well defined frontal ridge of shell and sand.

The marsh vegetation includes typical brackish marsh species, such as smooth cordgrass, three-cornered rush, bayonet rush, and that excellent indicator of saline conditions—saltgrass. Cane occurs only at the edge of the bayous; a zone of clump cordgrass grows along the frontal ridge.

History. This marsh has been heavily stocked with cattle each winter for years, 2,000 head in 1940. The stockmen who lease the grazing, burn the marsh in September and October to provide succulent greens by winter. To protect the cattle from disturbance, the stockmen have a provision in their lease which prohibits waterfowl hunting. Muskrat trapping, under lease, has been a side line to the grazing. No management efforts have been made, and the marsh is an example of improper burning and grazing.

Muskrat Populations and Conflicting Land Use. The better quality muskrat marsh amounts to about 2,500 acres of the 4,600. Records or the best available estimates of muskrat catches since 1923 are: 1923, 5,530; 1924, 8,000; 1925, 1,000; 1926, 800; 1927, 575; 1928, 27; 1929, 10; 1930 to 1934, none; 1935, 1,055; 1936, 4,895; 1937, 4,381; 1938, 20,580; 1939, 10,557; and 1940, 3,000. The causes for these great fluctuations are obscure, but there is indication that some of the many trapping leasers used every means to remove all muskrats without leaving breeding stock. Some of the trappers used pitchforks on the muskrat houses after stopping all exits and thus captured all muskrats of suitable size. Others resorted to trapping at or inside of the houses.

Improper Burning.—In August 1940 the marsh was burned by muskrat trappers to prevent later burning by cattlemen. The marsh was almost dry and the fire made a clean sweep, removing all cover. The remaining water evaporated rapidly and muskrats moved out across the bayous to adjoining unburned marshes. Had the marsh been wet, spots of cover would have remained and all muskrats would not have left the property. There was no rain until October, but two high salt tides covered the burned area in the meantime. The result was retarded recovery of the vegetation which otherwise would have been sufficient to entice the return of muskrats by early fall. After the fall rains, muskrats began to reoccupy the marsh but were forced to use roots and stubble for housing material. All winter the lower part of the marsh was a continuous body of open water with occasional bits of emergent vegetation, but several hundred muskrat houses appeared where some cover was available. In April 1941 the vegetative cover was still sparse and the area resembled a vast lake. The marsh vegetation will likely not recover for a year or more from such a serious burn followed by drought and salt tides.

Competition. By the end of December 1940 cattle had destroyed at least 150 of the new muskrat beds by resting on them, and had done an undetermined amount of damage to muskrat runways by trampling. Beds thus disturbed were not rebuilt.

The late recovery of the vegetation after burning and the protection from hunting attracted several large flocks of snow and blue geese that remained on the marsh almost constantly because there was heavy hunting pressure on all sides. Areas of marsh were converted to mud where the birds fed and rested. Their favorite food was the roots of the important muskrat food plants, bayonet and three-cornered rushes. Areas occupied by the geese were thus seriously reduced in value for muskrats; on some the damage was so serious that what remained resembled a marsh eaten out by muskrats and will not recover for several years. Hurricane wave action in such "eaten-out" spots of marsh causes the formation of ponds and when this occurs the loss of land to muskrats may be semi-permanent. Normal wave action in the ponds retards pioneering of marsh vegetation around the edges of such lakes (Pl. 28, *B*).

*Discussion.*This marsh demonstrates that clean-burning in summer seriously impairs meadow-like muskrat marshes, especially when dry weather or storm tides follow the burn. On marshes where rank vegetation such as sawgrass or cane does not occur, the burning of alternate strips every other spring seems justified. This practice insures cover at all times, and prevents a complete migration of fur bearers to other lands, conserves the marsh water supply, provides autumn vegetation too rank to be preferred by geese, and is sufficient to prevent formation of undesirable roughs of rank grass. The effects of excessive roughs on muskrat pelt quality have been reported from other marshes as distinctly detrimental. On an Orange County marsh, O. Vincent declares that the quality and relative market value of muskrat pelts declined steadily for three years coincident with protection from fires. Pelt quality was

normal again the winter following a spring burn. Cattle in the marsh destroy muskrat houses and force muskrats to move. The damage is so great that electric fences to keep cattle out of the better marshes are justified. Competition between geese and muskrats can be minimized by burning adjacent low prairies in autumn to attract the geese with new greens, and by moderate hunting on the muskrat areas.

MANAGEMENT OF TRAPPING

The present legal trapping season in Texas is from November 16 to February 15, but few of the major operators begin before December. The long season has the advantage of giving the private operator freedom to make allowances for weather, over-populations requiring thinning, and other local conditions; also to prevent physical damage to the marsh. The disadvantage of the long season is that it requires some trapping of border lines to prevent trespass by small, irresponsible trappers who take fur whenever they can regardless of primeness or the conservation of breeding stock. The muskrat breeding season varies from year to year but is most marked in February and March. The quality of fur does not approach the maximum until after December 1. Figure 2 shows the close relation between cool weather and success of muskrat trapping and points to the necessity of a season long enough to afford suitable trapping weather. When only a few spells of weather below freezing occur in one winter it is essential that trappers be free to operate at those times.

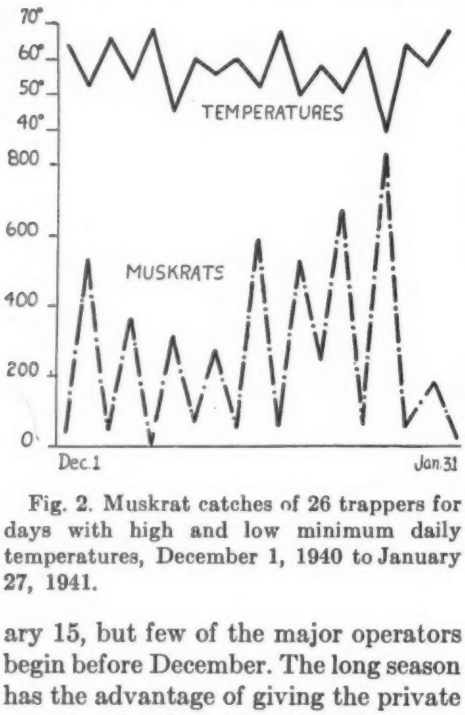

Fig. 2. Muskrat catches of 26 trappers for days with high and low minimum daily temperatures, December 1, 1940 to January 27, 1941.

Among trappers and others the theory is prevalent that trapping more than ten yards from beds prevents the capture of many breeding females and young. Our limited observations are not significant but show that many females and some young are taken more than ten yards from houses. Without further data it would be wise for conservative operators to prohibit trapping closer than ten yards from beds, but legislation to make the setting of traps within ten yards of beds illegal is not fully justifiable at present.

Distance of traps from beds, in yards	*Males*	*Females*	*Kits*
0– 5	1	3	—
6–10	4	6	1
11–15	2	4	—
16–20	7	5	1
21+	45	30	1
Totals	59	48	3

SUMMARY

1. The 260,000 acres of coastal marshes in Texas have produced a maximum crop of 350,000 muskrat pelts.

2. A study of fresh to slightly brackish marsh has demonstrated the value of severe burns in sawgrass and cane to encourage the increase of cattail, smooth cordgrass, and three-cornered rush.

3. Excluding all brackish water reduces the preferred muskrat habitat of brackish plant communities. Final success of a management program of burning and ditching is prejudiced by excluding brackish tides.

4. It is demonstrated that ditches drain off excess water, provide levees for muskrat travel lanes and rest during high water, and serve for access by trappers.

5. The value of alligators for making water holes and aiding to keep ditches open is recognized by trappers despite former prejudices against these reptiles as muskrat predators.

6. The brackish marsh study gave encouraging preliminary results in the improvement of low prairies by impounding water with levees and dams. On clay soils the formation of peat desired by muskrats for burrowing will be important in the ultimate success of efforts to make new muskrat marsh.

7. The brackish to saline marsh studied has not been managed; conflicting land uses involve practices harmful to muskrats. Clean summer burns when the marsh is dry forced muskrats to move. Return of the muskrats is discouraged by the lack of house-building material, even after rains. Cattle damaged muskrat beds and runways severely, forcing the muskrats to move.

8. Late summer burning attracted geese in great flocks, causing losses in muskrat foods and physical damage to the marsh. Such competition could be prevented by fall-burning of adjoining prairies to produce succulent greens and by spring-burning the muskrat marsh. Moderate hunting also helps to keep the geese from concentrating on a muskrat marsh.

9. Legal trapping seasons should be long enough to enable operators to trap in accordance with local conditions as to weather and muskrat populations. Traps set close to muskrat beds may be somewhat selective of breeding females and young.

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APPARATUS FOR MARKING WILD ANIMALS WITH COLORED DYES

James Moffitt

In studying the breeding behavior of sage grouse (*Centrocercus urophasianus*) in northeastern California during the spring of 1941, it became desirable to mark certain birds. The problem was to mark individuals on the leks or strutting grounds without unduly frightening them, so as to interfere as little as possible with their territorial and other activities. Trapping was hence ruled to be undesirable.

The males of *Centrocercus*, as of other plains-dwelling grouse such as *Pedioecetes* and *Tympanuchus*, congregate mornings and evenings in the breeding season on leks, usually in extremely barren situations, where they perform their nuptial dances. The leks may serve from four or five to a hundred or more males. Females in much smaller numbers come to the leks to select males and to breed with them there. The leks are situated in flat, open spaces with little or no cover which makes it necessary to use inconspicuous apparatus.

A blind constructed on a lek the previous autumn was by the spring of 1941, apparently almost unnoticed by the birds. By entering this blind before daylight, prior to arrival of the grouse at the lek, the birds were apparently unaware of the observer's presence and some individuals later performed within 25 feet of the structure. Many birds displayed and some occasionally mated, within 100 feet of the blind. To mark the individuals with various colors of dyes seemed to afford a promising means for facilitating the observation of territorial and breeding behavior.

As regards a suitable dye, experiments indicated that powdered commercial aniline dyes, soluble in water and alcohol, would be satisfactory. Bright blue, red, green, and yellow dyes were used, and by mixing them other colors such as purple and orange could easily be produced. No perceptible fading of colors was noted over two months when exposed to the bright desert sunlight or to rain, on feathers and other porous surfaces. Dye mixed only with water did not penetrate the feather structure but remained on the surface in droplets. Equal parts of water and 95 per cent grain alcohol readily and immediately penetrated the feathers. For convenience in transportation, the dye was mixed in the laboratory with the pure alcohol until a strong color concentration was obtained and taken to the field where an equal volume of water was added before use. In the course of the experiments, the final mixture was left for several nights on the leks during temperatures below freezing, when the alcohol supplied the desirable quality of an anti-freeze solution.

Apparatus which was unsuccessfully tried in March, 1941, will be mentioned briefly because it would probably work satisfactorily for other species and under different conditions.

Bombs were made by holding old-style electric bulbs with pointed-tips under the dye solution and breaking the tips off, when the vacuum drew

them full of dye. When thrown at a bird they broke upon striking the ground with a considerable splash of liquid, but because of the cramped quarters in the blind and the writer's poor aim, no bird was marked in several attempts.

Apparatus more promising of results, which worked satisfactorily in the laboratory, consisted of refillable "Sparklet" syphon bottles connected by rubber tubing to sprinkler heads and tripped from a distance by pulling a cord attached to the discharge lever. These bottles contain one quart of liquid and may be purchased for about $3.50 each, wholesale, or for $5.00 retail. Upon filling, pressure is generated by releasing the contents of a capsule containing liquified carbon-dioxide gas into the bottle. The absorption of this gas by the alcohol and water solution used is much less than with pure water, for which the bottles are intended, but no trouble was experienced in charging a number of bottles filled with the dye mixture. In all cases, the gas was released very slowly while the bottles were vigorously agitated to obtain rapid and maximum solution of the gas in the liquid.

Bottles so charged were connected by a 12 inch length of rubber tubing $\frac{3}{8}$" inside diameter to an iron pipe nipple of similar diameter. The latter was screwed through a $\frac{1}{2}$" to $\frac{3}{8}$" reducing bushing into a "Ross" 360-degree garden sprinkling head. This apparatus, charged with liquid and including the bottle, sprinkler and connections weighed only 5 pounds. The entire apparatus was buried beneath the surface except the sprinkling head, which was wired to a stake and permitted to protrude about two inches above ground (Pl. 29, *A*). The bottle was placed so that the discharge lever faced away from the blind and a cord attached to the latter was led to the blind. Upon pulling the cord, the contents of the bottle were discharged through the sprinkler head.

Tests of this apparatus made in San Francisco at about 65° F. air temperature indicated that it might be successful, as the liquid sprayed over an area about ten feet in radius from the sprinkler, for about five seconds. The initial burst was the strongest and it instantly marked objects in its path with sufficient dye to color them well.

Accordingly, four such bottles and connections were taken to a sage grouse lek in March. There they were buried in the ground, each near a cock's strutting territory. This operation was done during the day while the birds were absent, in order not to disturb them. The bottles were left buried over night and attempts to mark the birds were made early in the following morning. From the low point of vision afforded by the blind, it was difficult to determine exactly where a sprinkler head was located. The location of each bottle had been marked by a line, but it was impossible to judge accurately where the sprinkler head or the bird was located on this line. Accordingly considerable range of the spray, to at least ten feet, was required to overcome these inaccuracies. A bottle was discharged when a grouse was thought surely to be within this range of the sprinkler. Upon pulling the cord, however, the liquid did not spray over a 20-foot circle as it had done in San Francisco, but with a weak discharge

covered an area scarcely four feet in radius. No bird was successfully marked that morning or in attempts on several subsequent days. Obviously, the apparatus was inadequate for the purpose intended.

The trouble was readily determined to be the property of water to dissolve much more carbon-dioxide gas when cold than at higher temperatures. The bottles lay buried shallowly during nights when the early morning temperatures averaged 20° F. The liquid then dissolved so much of the gas that little of the latter was left free to expel the solution. It seems probable that this relatively cheap, light-weight, and simple apparatus may be used successfully for marking animals in warmer climates, or under conditions where their close proximity to the sprinkler head can accurately be determined.

Upon returning to the museum shortly after this failure, the problem was taken up with our mechanically adept Curator of Paleontology, Dr. G. Dallas Hanna and with Mr. W. M. Grant, Consulting Engineer of the Academy. They were exceedingly helpful in developing the apparatus next to be described, which successfully marked the grouse. Acknowledgment is gratefully made for their assistance.

Believing that the sprinkler spray method was theoretically practical for the purpose, if sufficient range could be developed to overcome inaccuracies in judging the position of a bird in relation to the sprinkler, apparatus was designed with an increased spray range and not affected by low temperatures.

Dr. Hanna suggested the use of compressed air cylinders and releasing the air through a valve upon a container of liquid. This seemed to require rather complicated, costly, and heavy apparatus, so the idea was modified to a container in which relatively high air pressure could be applied to the liquid in one unit. Containers (Pl. 29, *B*) were constructed from 12-inch lengths of oil well casing, 6 inches in inside diameter, by welding a $\frac{3}{8}$-inch steel plate into either end. Each container held slightly more than a gallon of liquid. A pipe nipple, $\frac{1}{2} \times 4$ inches, was welded into the bottom at one end for the liquid to pass through, and a 90° elbow on the end of the nipple directed the stream upward as the cylinder lay on its side. A $\frac{1}{2}$-inch brass globe valve with quick-opening and self-closing spring lever action was attached to the elbow by a $2\frac{1}{2}$-inch pipe nipple. This brought the top of the valve to the level of the top of the tank, as it lay on its side, with the exit pipe at the bottom. For use on sage grouse, it was desired to bury the tank out of sight and to have the sprinkler head project just above the surface of the ground; hence, the sprinkler was attached to the top of the valve through a 2-inch nipple and the tank was buried with its top this distance underground.

On the top side of the cylinder, near the end opposite to the nipple and directly opposite as regards the tank's diameter, an old-style, straight-shanked auto tire valve stem was screwed into a hole drilled and tapped through the tank wall to receive the stem. The stem was cut and threaded to extend $2\frac{1}{2}$ inches above the top of the tank, the same distance as the top of the sprinkler head. This permitted refilling and recharging the tanks through the half inch liquid valve and through the air

A. Refillable siphon bottle and spray head, buried to broken line; not successful on sage grouse, possibly useful for coloring other animals. *B*. Iron spray tank used to color sage grouse; buried in ground to broken line. *C*. Spray tank buried on sage grouse lek. Arrows point to: *1*, air valve stem; *2*, spray head; *3*, discharge lever.

UNIV. OF MICH.

valve stem while they lay buried. To pour liquid through the valve into the cylinder it was only necessary to remove the valve insert and the sprinkler head and to hold the valve lever at open position. When filled, the valve lever was closed and the sprinkler head and air valve insert replaced. Then air was pumped through the latter to the desired pressure.

The entire apparatus, empty of liquid, weighed 26½ pounds. This had its disadvantages, but the writer had no difficulty in carrying two such tanks charged with liquid for a quarter of a mile over rocky ground. The total cost was about $6.00 per tank, as Dr. Hanna contributed the oil well casing sections. New pieces of 6-inch diameter iron pipe would cost about $1.25 each, making the total cost of a tank approximately $7.25. The valves cost $3.25 each, wholesale; the sprinkler head 50 cents, and the miscellaneous pipe fittings and air valve stem, another 50 cents. The steel ends and the welding work together cost $1.75 per tank.

All pipe connections from the cylinder to the liquid valve and the air valve threads were coated with a mixture of litharge and glycerin and screwed up tightly to make the tanks airtight. Experiments later showed no leaks and the tanks held a pressure of 120 pounds per square inch for three days. Some difficulty was experienced at first by air leakage through the rubber valve-seats, particles of metal from the welding having stuck in the valve-seats. No further leakage occurred after the tanks were thoroughly cleaned of particles.

Two such tanks were constructed and tested in the museum. To provide a reserve of air in the cylinders experimentation showed that best results could be obtained with the cylinders about half full of liquid, or charged with slightly more than two quarts of dye mixture. The remaining space was available for compressed air. Further experiments with various air pressures. indicated that effective sprays which did not diminish in intensity until the liquid was exhausted were obtained equally well from pressures of from 70 to 120 pounds per square inch. A comfortable factor of safety was provided by the strong construction of the tanks, which would probably withstand pressures far in excess of those used.

When charged with liquid and air pressures in the above ranges, the tanks were discharged by a cord attached to the valve lever which was set so that a direct pull away from the tank would open the valve. Thompson Patent, high-pressure, adjustable sprinkler heads, were found to spray more liquid in a given length of time and slightly farther than the "Ross" sprinklers. A maximum radius of 15 feet from the sprinkler was heavily covered with liquid in the 5 seconds required to discharge completely the liquid contents of the tanks. An area 25 feet in diameter centering at the sprinkler was most effectively sprayed so that any animal within this range of the sprinkler would be well colored before it had time to escape.

As a result of these experiments, the new tanks were taken to the same sage grouse lek on April 15, 1941, with a feeling of considerable confidence that the birds could successfully be colored. The tanks were half filled with dye solusion and charged to 120 pounds pressure at a service station en route. Before

burying the tanks on the strutting ground, the bright sprinkler heads and valve stems, the only parts that would extend above ground, were painted with brown lacquer, and while this was still wet, dust from the strutting ground was cast on the paint where it stuck. This rendered these parts practically invisible when the tanks were buried (Pl. 29, C). This precaution was thought to be necessary as a result of experience gained in March when it appeared that the sage grouse avoided close proximity to the unpainted brass sprinkler heads then used.

After burying the cylinders so that the sprinkler head, valve lever, and air-valve stem of each projected just above the surface of the ground, the adjacent area was cleared of debris and restored to its original condition. A length of no. 36 brown seine twine that closely matched the ground in color and was thus quite inconspicuous, then was attached to the valve lever and extended across the lek to the blind, about 75 feet distant from each tank.

To permit the birds to get accustomed to the presence of the tanks, should they have noticed them, which seems doubtful, the tanks were left in place and the lek was not again visited until early on the morning of April 18. While it was dark and before any grouse had arrived, the tanks were checked for air pressure by an air gauge applied to the valve stems. The pressure had not diminished, so all seemed to be in readiness with the cords clear of obstructions from the tanks to the blind. The writer then entered the blind a half hour before daybreak.

Grouse soon arrived on the lek and before 5 a.m., when it was still twilight, most of them were in their appointed locations. An hour later, the only three female grouse that were present that morning were close to a male directly in front of the blind and all were near a sprinkler head. The cord to this tank was pulled when it appeared that all of the birds must have been marked with the red dye that this cylinder contained. The male was nearest to the sprinkler, probably not over three feet distant, and facing it. When the spray went off he flew directly through the stream and continued on for about 75 yards to alight at the edge of the lek. The females, which it was later determined were just outside the range of the spray, were accordingly missed by the liquid. As the spray went off, each hen fluttered a few feet in the air for a moment, then alighted near the same spot. Other grouse within 75 feet of the sprinkler ceased strutting and stood alert for about two minutes following its discharge; then they resumed their usual activities. Grouse farther away on the lek paid no attention to the spray.

The time from the instant the spray was set off until the birds were beyond its range when the valve was closed, did not exceed two seconds. Thus, less than half of a tankful was required for spraying. Later experiments indicated that more than sufficient liquid and pressure remained for a second spraying; then it was necessary to refill and recharge the tank.

The male that was colored remained where he had alighted at the edge of the lek for eight minutes. During the first half of this time, he stood hunched up and occasionally shook his head. This action probably resulted from the alcohol solution having sprayed his eyes and causing them to smart; but the solution was too dilute to injure the tissue. The

bird resumed some activity in the second half of this interval, after which he walked slowly back to his territory, the center of which was now stained bright red. He walked about on the stained ground in a nervous manner for four minutes, and strutted but three times in this period. The bird evidently sensed the presence of danger, but could not identify it. After this interval on his territory, the cock walked to the sagebrush at the edge of the lek, 75 feet west of the red spray, where he strutted intermittently for 13 minutes. He then flew eastward, directly across the lek, to alight 50 yards east of his old territory. There, he strutted for a short while and then ceased displaying and commenced eating sage leaves. Apparently he later walked off into the sagebrush for he was not seen again that morning, although other cocks remained on the lek nearly an hour longer, until frightened away by the approach of sheepherders.

This sage cock had been colored bright red all over his head and neck, and apparently on his entire under surface, but the dye did not show on the areas where the plumage is black. He could be recognized easily when standing, by his red breast and face from the front, or by the red on his under tail coverts from the rear. In flight, the entire under surface of his wings were stained bright red and he could have been identified by these markings at a quarter of a mile.

The three female grouse which were just missed by the spray and which, next to the marked male, were more frightened than any of the other birds present, resumed their normal activities soon after the spraying. One of these females flew from the strutting grounds 40 minutes after the experiment and another hen left 20 minutes later; but this was normal behavior for females at that season.

Observations were made on this lek on the following two mornings in an endeavor to mark some hens, but few visited the males due to the lateness of the season and none was marked. Even had a female been colored, little information would have resulted, for normal breeding seemed to have ceased for the season.

On these visits, however, the red colored male was found at all times in his original territory where he had been sprayed. There, he seemed to behave perfectly normally the morning following his marking, when his presence could be determined as early as 4:35 a.m., while it was still quite dark; his breast then appeared to be black, whereas those of the other cocks showed light in the poor visibility. On these two mornings, many interesting observations were afforded by this marked bird; these are reserved for a future paper on sage grouse behavior.

The behavior of this sage cock following heavy spraying with the dye solution indicated that temporary mild discomfort and some interruption of the bird's routine may result, but the effects soon disappear and entirely normal behavior is resumed within 24 hours. Furthermore, the behavior of other birds on the lek was not interfered with for more than a few minutes following the spraying. The method appears, therefore, to be a satisfactory means for marking this species, and can be adapted for the coloring of many other kinds of wild birds and mammals as well.

One unanticipated factor that must be reckoned with and compensated for

is wind which tends to drift the spray in an oval pattern to the windward of the sprinkler. The cock was marked on a windy morning and had this condition not existed, it is thought that the hens which were slightly up wind from him, would have been successfully colored. Probably only experience and practice will show how to compensate for this condition.

It is thought that these tanks can be used for marking many kinds of birds near the ground level. By increasing the length of the pipe between the valve and the sprinkler head, it seems probable that the latter can be elevated some six or eight feet above the tank. Thus, birds in low trees could be sprayed; or the tank could even be tied up in a tree and birds thus be sprayed in higher situations. If a long stand-pipe is used between the valve and sprinkler, it would seem advisable to fill the pipe to the sprinkler with the liquid before attempting to use the apparatus. This would eliminate the rush of air out of the pipe which might frighten a bird before the dye sprayed, which would result if this precaution were not taken.

Many kinds of sprinklers can be used on these tanks. Half and quarter circle sprinkling heads are available, as are also jet types which might be trained upon a perch which a bird is known to frequent and thus concentrate the stream on this area. It is possible also to direct the spray either vertically, horizontally, or obliquely, by using an elbow of various degrees turn between the outlet valve and the sprinkling head, or to change the direction of the spray slightly by turning the tank on its long axis to one side or the other; also, a short piece of hose fitted with a jet spraying nozzle may be attached to the valve exit nipple in place of a sprinkling head. The writer experimented with such a device, using a six-foot length of hose. The tank was set upright on the ground and the valve lever was operated by foot, leaving both hands free to direct the nozzle. A jet spray was thus thrown a distance of 40 feet for a 5-second interval. The spray developed maximum range so rapidly that it was thought possible to thus color a bird by suddenly rising from a blind and spraying before it could fly off. This apparatus was taken to the sage grouse lek, but no occasion developed to use it.

Other modifications that present themselves for use of the tanks involve spring trap trips arranged so that the sprays could be set to be tripped by some of the larger kinds of birds and mammals and color them. A spring or weight arrangement could be attached to the discharge valve lever and connected to a trap so that when sprung it would pull the lever and discharge the spray. This method might effectively be used for marking birds like raptors on their perches, or by using a thread trip or photo-electric eye device across the trail of a mammal, to color deer, coyotes, or wolves.

Finally, it seems probable that the dyes used will be effective only on plumage or pelage of moderately light color. It would be difficult to mark blackbirds, unless bright yellow dye would prove to be recognizable. The development of some white pigment base might be necessary to satisfactorily mark solidly dark animals.

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FISHERIES INVESTIGATIONS IN CRATER LAKE, OREGON, 1937–1940[1]

Arthur D. Hasler and D. S. Farner

This paper summarizes an investigation on the fishery biology of the rainbow trout (*Salmo gairdnerii irideus*), and the silver salmon (*Oncorhynchus kisutch*), at Crater Lake, Oregon, from 1937 to 1940. A preliminary report by Hasler (1938) analyzed the observations of 1937 and gave a brief description of the limnological features.

Methods

A creel census conducted each summer through the cooperation of Paul Herrin, E. Wilcox, the ranger staff, and CCC workers recorded about 90 per cent of the catch by all anglers. This favorable return resulted from the fact that only one trail to the lake was in passable condition and the only boat concession on the lake was at the base of this trail. Some natives of the region may have reached the lake by devious passes and fished from rafts or from shore, but shore fishing has proved to be unfruitful, and fishing by this group is assumed to be less than 10 per cent of all angling.

A group of fishes was selected at random from the angler's creel each day for study of growth and survival of year classes, and to obtain general fishery information. Each fish was weighed and measured, its sex determined, and a few scales removed from below the dorsal fin. The data were analyzed according to procedures introduced by Hile (1941). The observations recorded here on the growth of salmonids serve only to interpret fishery problems and not as a contribution to the techniques of scale analyses.

[1] Aided by the National Park Service, CCC, NYA, and the Department of Zoology, University of Wisconsin.

Growth

An analysis of the growth of each year-class (fish originating from the hatch of a particular year) beginning with the stocking of fry and the natural hatches of 1932 is recorded graphically for the trout (Fig. 1) and the silver salmon (Fig. 2). The curves summarize the data presented in Tables 1 and 2. The growth history of each age group was divided into annual increments, and the grand averages of the annual increments used to construct an average growth curve.

When the broken line connecting the calculated lengths of the same year of life is followed (Fig. 1) it will be seen that the first year of growth in each year-class is fairly uniform except for that of 1938 in which it exceeded all others. This last may not be representative because only 19 fish are represented. Perhaps, too, only the faster growing members of the year-class were large enough to take the anglers' lures in early life. Catches of the 1938 class may be expected to smooth out this curve in subsequent years as it appears to have done in the previous year-classes.

The growth of the salmon (Fig. 2) also shows a tendency toward greater lengths in the younger fishes. This too may be because only the larger individuals were caught by angling. The tackle

TABLE 1
RAINBOW TROUT—AVERAGE LENGTH AT CAPTURE, AND AVERAGE CALCULATED LENGTH BY AGE GROUPS, YEAR-CLASSES, AND YEAR OF CAPTURE

Year class	Year captured	Age group	Number of fish	Average length at capture (inches)	Average calculated length (inches) at end of each year of life					
					1	2	3	4	5	6
1932	1937	V	9	19.7	2.7	6.0	10.9	14.4	18.7	
	1937	IV	56	17.3	2.8	5.7	11.2	16.1		
1933	1938	V	17	19.3	3.0	5.9	10.9	15.0	18.7	
	1939	VI	2	18.9	3.5	5.5	7.0	10.4	15.4	18.3
	1937	III	49	15.9	3.6	8.2	13.8			
1934	1938	IV	79	16.9	3.0	5.9	10.9	16.0		
	1939	V	5	17.6	2.3	4.5	7.5	10.0	14.9	
	1940	VI	3	20.8	3.6	5.7	7.8	13.4	16.2	17.5
	1937	II	9	13.6	4.6	9.5				
1935	1938	III	19	15.8	3.4	7.0	12.9			
	1939	IV	8	17.7	3.8	7.9	11.8	15.9		
	1940	V	5	16.6	2.4	5.9	6.9	10.4	14.5	
	1938	II	7	10.4	3.6	7.9				
1936	1939	III	7	14.5	3.0	7.1	11.8			
	1940	IV	5	15.2	3.7	8.6	11.5	13.4		
1937	1939	II	11	10.7	3.4	7.9				
	1940	III	8	13.8	3.0	6.7	11.4			
1938	1939	I	7	9.6	6.6					
	1940	II	12	11.0	4.0	8.7				

TABLE 2
SILVERSIDE SALMON—AVERAGE LENGTH AT CAPTURE AND AVERAGE CALCULATED LENGTH BY AGE GROUPS, YEAR-CLASSES, AND YEAR OF CAPTURE

Year class	Year of capture	Age group	Number of fish	Average length at capture (inches)	Average calculated length (inches) at end of year of life				
					1	2	3	4	5
1933	1937	IV	14	17.6	3.2	6.7	11.6	15.8	
1934	1937	III	74	16.3	4.2	8.9	14.1		
	1938	IV	5	20.9	3.5	6.9	12.0	17.0	
	1937	II	61	14.6	4.0	9.0			
1935	1938	III	24	15.5	3.1	6.5	12.8		
	1939	IV	38	15.1	4.0	5.8	9.7	13.0	
	1937	I	2	5.3	3.6				
1936	1938	II	1	7.5	3.5	7.0			
	1939	III	49	15.6	3.9	6.8	12.4		
1937	1939	II	54	13.3	4.4	10.5			
1938	1939	I	11	9.0	5.6				
	1940	II	23	10.2	4.0	7.7			
1939	1940	I	75	10.0	5.4				

TABLE 3
RAINBOW TROUT—REPRESENTATION OF YEAR-CLASSES IN COLLECTIONS OF DIFFERENT YEARS

Year of capture	Item	Year-classes									Total captured
		1930	1932	1933	1934	1935	1936	1937	1938	1939	
1937	Age group	VII	V	IV	III	II					
	Number	1	9	56	49	9					124
	Percentage	0.8	7.2	45.0	39.6	7.3					
1938	Age group	VII		V	IV	III	II	I			
	Number	1		17	79	19	7	1			124
	Percentage	0.8		13.7	63.8	15.3	5.7	0.8			
1939	Age group			VI	V	IV	III	II	I		
	Number			2	5	8	7	11	7		40
	Percentage			5.0	12.5	20.0	17.5	27.4	17.5		
1940	Age group				VI	V	IV	III	II		
	Number				3	5	5	8	12		33
	Percentage				9.1	15.1	15.1	29.2	36.4		
	Totals										
	Numbers	2	9	75	136	41	19	20	19		321
	Percentages	0.6	2.9	23.4	42.4	12.8	5.9	6.2	5.9		

used by the anglers has been very uniform throughout. Lee's phenomenon also may play a role in explaining the apparent small first-year growth of the older fishes.

The 1934 year-class of trout exceeded all others in yield, being 42.4 per cent of all captures (Table 3). The 1933 and 1935 year-classes were next in amount (23.4%, 12.8%) whereas the classes of

TABLE 4
SILVER SALMON—REPRESENTATION OF YEAR-CLASSES IN IN COLLECTIONS OF DIFFERENT YEARS

Year of capture	Item	Year-classes							Total captured
		1933	1934	1935	1936	1937	1938	1939	
1937	Age group	IV	III	II	I				
	Number	14	74	61	2				151
	Percentage	9.3	49.0	40.4	1.3				
1938	Age group		IV	III	II				
	Number		5	24	1				30
	Percentage		16.7	80.2	3.0				
1939	Age group			IV	III	II	I		
	Number			38	49	54	11		152
	Percentage			25.0	32.2	35.5	7.2		
1940	Age group						II	I	
	Number						23	75	98
	Percentage						23.5	76.5	
	Totals								
	Numbers	14	79	123	52	54	34	75	431
	Percentages	3.2	18.3	28.4	12.1	12.7	7.9	17.4	

1936, 1937, and 1938 provided only 5.9, 6.2 and 5.9 per cent of all captures.

As to salmon (Table 4), the 1935 year-class constituted 40.4 per cent (age group II) of the 1937 catch, 80.2 per cent (age group III) of the 1938 catch, and 25 per cent (age group IV) of the 1939 collection. The 1939 year-class gave promise of being another strong group, providing 76.5 per cent of the captures in 1940.

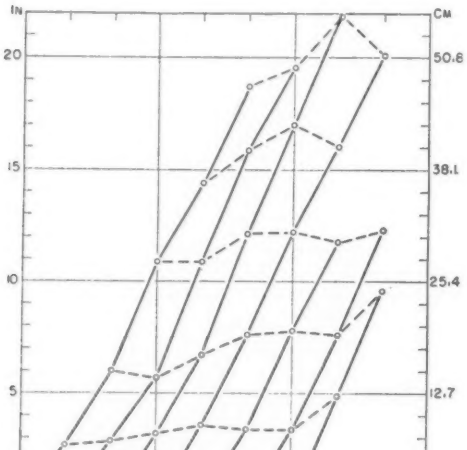

Fig. 1. Calculated growth of year-classes of rainbow trout. Calculated lengths for corresponding years of life in different calendar years are connected by broken lines.

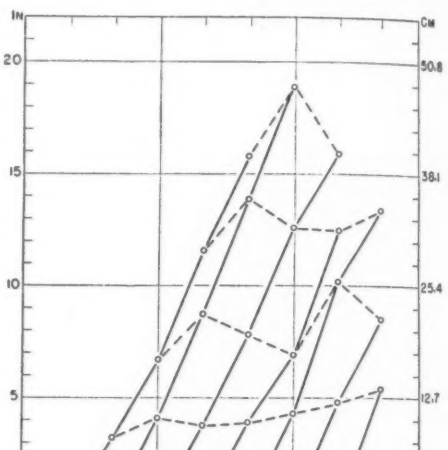

Fig. 2. Calculated growth of year-classes of silver salmon. Calculated lengths for corresponding years of life in different calendar years are connected by broken lines.

In Wisconsin rock bass (Hile, 1941) the numerical strength of a year-class has a definite correlation with good growth. No such correlation is evident in the Crater Lake salmonids when the growth curves (Figs. 1 and 2) are compared with the year classes (Tables 3 and 4); but if fishes of the same age group taken in different years (Tables 1 and 2) are compared as to amount of growth, it becomes apparent that the trout of age groups III, IV, and V showed better growth in 1937 and 1938 than similar ones in 1939 and 1940. The favorable growth can be correlated with the strength of the year-classes, since the greatest number of the strong year-classes of 1933 and 1934 were captured in 1937 and 1938.

With the salmon, those of age group I caught in 1940 had attained a length of 10 inches when captured, exceeding any other group I of any year. As stated above, these fishes showed indications of continuing as a strong year-class. Age group III of the strong 1934 year-class also was abundant in the 1937 captures. Furthermore, this age group II grew more in that year than similar ones in other years. Contrarily, in the strongest year-class, 1935, the age group III of the 1938 captures does not exceed the growth of other groups. Consequently good growth is not always correlated with strong year-classes.

Hile (1936; 1941) found some correlation between good growth and strength of year-classes in ciscos and rock bass with meteorological and limnological fluctuations. He reviews the work of others who have found similar correlations in other species. These changes also have been shown to affect the survival of a new hatch. These correlations are interesting, but not within the scope of this paper. Some correlations probably could be found if complete meteorological and limnological data were available.

The greatest difference in sex ratio was in group I of salmon caught in 1940, 79 per cent of males being recorded. As a rule, however, the females predominated in the older age groups of both yields species.

Observations continue to support the evidence of the 1938 report that the life cycle of the salmon in Crater Lake is four years.

Little variation has been noted in the general condition of the fishes from year to year.

CREEL CENSUS

A summary of the creel censuses (Table 5) shows that more fishes were caught per hour of angling during July than in August in all years. In 1938 a study was made to compare day fishing and evening fishing by a group of rangers who kept separate records of their angling before and after 3:00 p.m. During July and August they fished 26 hours between 8:00 a.m. and 3:00 p.m. and caught an average of 0.17 fish per hour per angler. The same men, using identical tackle and in the same months, also fished between 3:00 p.m. and dusk and then averaged 0.86 fish per hour per angler. Boats are not available to the public for early morning or evening fishing, because of local conditions; otherwise anglers would obtain greater yields.

NATURAL REPRODUCTION VS. STOCKING

If we assume random sampling for the scale collections, the percentage composition of the year-classes as recorded in Tables 3 and 4 can be applied to the

TABLE 5
SUMMARY OF CREEL CENSUSES AT CRATER LAKE, OREGON

Month	Boat reports	Anglers	Boat fishing hours[a]	Fish taken					Fish per	
				Total	Trout		Salmon		Boat-hour	Angler-hour
July 1937	317	634	920	767	310		457		0.83	0.42
July 1938	149	298	476	248	201		47		0.52	0.26
July 1939	194	376	1,182	772	75		697		0.65	0.32
July 1940	248	493	1,519	2,755	116		2,639		1.78	0.91
Aug. 1937	318	636	794	535	283		252		0.66	0.33
Aug. 1938	178	356	447	176	141		35		0.39	0.19
Aug. 1939	119	234	597	204	38		166		0.34	0.17
Aug. 1940	177	344	978	1,433	74	Ave. Length	1,359	Ave. Length	1.46	0.75
Total 1937	635	1,270	1,714	1,302	593	16.5	709	15.6	0.76	0.38
Total 1938	327	654	923	424	342	16.5	82	16.1	0.46	0.23
Total 1939	313	610	1,779	976	113	13.7	863	14.2	0.55	0.28
Total 1940	425	837	2,497	4,188	190	13.9	3,998	9.9	1.68	0.85

[a] Boats used for less than 1 hour are not included.

catches reported in the creel census (Table 5) and the yield of the year-classes correlated with the history of stocking (Table 6). There was little or

TABLE 6

STOCKING RECORDS FOR CRATER LAKE, OREGON

Year	*Rainbow trout*	*Silver salmon*
1932	319,000	None
1933	150,000	200,000
1934	None	54,000
1935	20,000	100,000
1936	25,000	25,000
1937	100,000	50,000
1938	None	None
1939	100,000	None

no correlation between stocking and yield to the creel. Indeed, the largest catch of trout was from the 1934 year-class. There were no fishes planted in that year according to the official records of the Park. There was also a catch of trout of the 1938 year-class in which year no fishes were planted. These data show that natural reproduction plays a dominant role in the maintenance of the population and stocking, by present methods, only a minor one.

Similarly there was a large catch of salmon from the 1939 hatch in which year none was stocked. There was also a catch of salmon of the 1938 hatch when none was stocked, which indicates that salmon reproduce in the lake.

STOMACH CONTENTS

During the summer of 1940, 79 stomachs were collected from fishes taken by anglers. Data on weight, length, and sex were recorded, and ages determined by examining the scales. No differences in food habits could be noted between the two species or among the various age groups within each species. Apparently the relative amounts of the various items in the diet depend upon the availability of these foods (Table 7). In August there were many terrestrial insects floating on the lake surface and these constituted a much larger proportion of the diet than in July when very few were observed. Brode (1938) found that *Daphnia* made up a considerable part of the diet of both species. One stomach collected in 1940 contained *Daphnia*. Furthermore, no *Daphnia* were found in tow-net samples from 100 meters to the surface, and none was found in Fumerole Bay where numbers were reported by Hasler (1938).

TABLE 7

STOMACH CONTENTS OF SALMONIDS IN CRATER LAKE, 1940

Items	*July*		*August*	
	Stomachs	*Average Number of items*	*Stomachs*	*Average Number of items*
Miscellaneous insects from surface	8	5	12	141
Midge larvae	14	733	9	77
Midge pupae	17	31	3	10
Caddis larvae	1	450	4	194
Hyallela	5	45	4	139
Snails	6	6	7	20
Miscellaneous aquatic insects and larvae	5	9	8	2
Daphnia	0	0	1	2,500
Empty	5	—	3	—
Totals	39		40	

FISHERY MANAGEMENT PROBLEMS

Alm (1939) found that salmonid fishes in Lake Vättern, Sweden, grew 4.8 inches per year over a 5-year life span. Cooper (1940) recorded the growth of salmonids in Maine lakes to vary from 3.3 to 5.8 inches between the fourth and fifth years of life. Ricker

(1938) recorded growth of 4.9 inches between the first and second years of life in the sockeye salmon of Cultus Lake, British Columbia. Schindler (1940) recorded the growth of two races of salmonids in an Alpine lake in Bavaria, where one grew 4.2 inches in both the first and second years, whereas the other grew 4.4 in the first year, 4.2 in the second, and 3.6 in the third. As compared with fishes in the lakes just mentioned, it is obvious that growth in the Crater Lake fishes is nearly at the optimum. There is no evidence of crowding or that the density of present fish population is injurious to good growth.

The potential production of salmonids in Crater Lake appears to be greater than the actual production. In 1940, when the maximum catch was recorded, we estimated that only 3.2 fishes (about 4 pounds) were caught per acre. If the fishes that died from natural causes could be added, the true productivity figure would be much greater. The actual catch at present is much below the possible catch since only a fraction of the area of the lake is available to anglers. Current facilities limit intensive fishing to within about a 2-mile radius of the boat livery.

Wingfield (1940) reported that brown trout do not grow at temperatures lower than 6°C. If this condition applies to Crater Lake salmonids, it would mean a long growing season (see records of summer temperatures in Hasler, 1938). Early spring, late fall, and winter temperatures have not been recorded. The lake never freezes over completely and the autumn is protracted; such a long period of moderate temperature would be favorable to growth.

Young fry were observed on many occasions, but attempts to catch them failed prior to the stocking periods; consequently no proof of natural reproduction was gained until the scale method of age determination was applied. No fishes of either species were planted in 1938, but in 1939 and 1940 fishes were caught whose scales indicated they were hatched in 1938. Likewise no salmon were stocked in 1939, yet those of the 1939 hatch were dominant in the creels of 1940.

Early indications of natural reproduction are found in the historical records. On December 6, 1901, the geologist J. S. Diller, wrote to Judge W. G. Steele (letter in files of National Park Museum, San Franciso): "Am very glad to learn that you put some fish in Crater Lake as early as 1888. It is probable that the ones we saw [summer, 1901] were some of your plant. We saw over twenty, so that it is probable your thirty-seven must have multiplied somewhat or else we happened to come across a large number of the members of your family. We saw no small ones whatever. Those we saw ranged from about six inches to the neighborhood of thirty inches in length, and the larger ones were generally more or less white [probably a *Saprolegnia* infection common in Crater Lake fish] on the back and sides as is often the case with old salmon far up in the rivers . . . " These, however, could have been fishes reportedly planted by a California minister before 1900.

It has been supposed that lack of adequate spawning areas would prevent salmonids from reproducing sufficiently to maintain themselves. Hobbs (1940) observed New Zealand trout to spawn

successfully on areas other than on loose, clean gravel, namely gravel admixed with finer materials and to some extent consolidated. There are no fine gravel beds in Crater Lake where most of the shores are underwater cliffs with only occasional submerged underwater "talus slopes" of angular stones ½ inch in diameter or larger. Shortage of what man calls "appropriate spawning grounds" has not prevented natural reproduction.

The fact that both species of salmonids are reproducing in the lake offers a problem of fish management previously supposed to be non-existent. Our data indicate that variations in the population can not be ascribed to stocking. Certainly the numbers of both species stocked in the past, are such that the volume of planting has not been injurious to growth of the population. From the growth rate it is apparent that population pressure could be increased without retarding growth materially.

In the past, two experiments have been tried. First, the stocking of small numbers (a maximum since 1932 of 26 per acre) and second, no stocking whatever. The planting of tagged fingerlings would yield interesting information on migration, both vertical and lateral, and on survival.

Serious thought should be given to the desirability of planting large numbers of fishes in a lake inaccessible to motor vehicles. If it be assumed that there is no natural reproduction and that all fishes in the creel originated from stocking, we estimate that every fish an angler catches, cost the government approximately 83 cents. This would mean that about only 0.008 per cent of the fishes planted got into the fishermen's creels. It is not known, however, how much the stocking has helped to keep up the population in the years when there has been heavy mortality from natural causes. R. R. Huestis (in manuscript, 1939) has recorded an epizootic of *Saprolegnia* that killed many fishes. Apparently this disease has been a factor for a long period, as Diller in his letter of 1901, mentioned "white patches" on the salmon. It would not be advisable to eliminate stocking entirely, because natural mortality may be so large as to necessitate periodic restoration.

SUMMARY

1. Natural reproduction of both silver salmon and rainbow trout in Crater Lake has been proved by the scale method. The strong 1934 year-class of trout originated from a natural hatch and it constituted 42.4 per cent of all captures over a 4-year period. No salmon were planted in 1939 but that year-class of salmon constituted 76.5 per cent of the 1940 captures.

2. Fishing was more successful from 3:00 p.m. until dusk than earlier in the day.

3. More fishes were caught in July than in August each year.

4. The proportions of the various foods in the diet of Salmonids apparently depends upon their availability.

5. In general, good growth was correlated with a strong year-class in both species. There was no evidence that the present population density is injurious to good growth.

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WINTER RELATIONS OF BOBCATS TO WHITE-TAILED DEER IN MAINE[1]

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The status of bobcat (*Lynx rufus*) predation on deer in the northeast seems to be somewhat clouded by controversy. The idea that bobcats may at times kill deer in numbers has been given very little credence. The present trend apparently is to consider the species an unimportant enemy of deer. Food habit studies in Michigan by Dearborn (1932) and Stebler (1940) and in California by Grinnell, Dixon, and Linsdale (1937) have not shown the bobcat to be a serious deer predator. Hamilton and Hunter (1939) studied 140 Vermont bobcat stomachs and found that more deer flesh had been eaten than any other kind, but, lacking sufficient information on actual bobcat-deer relationships, they were inclined to believe that most of the material was carrion from wounded deer left to die in the woods. Young (1928), Newsom (1930), and Grinnell, Dixon, and Linsdale (1937) cite scattered instances of bobcats being known to kill deer, four specific cases being recorded.

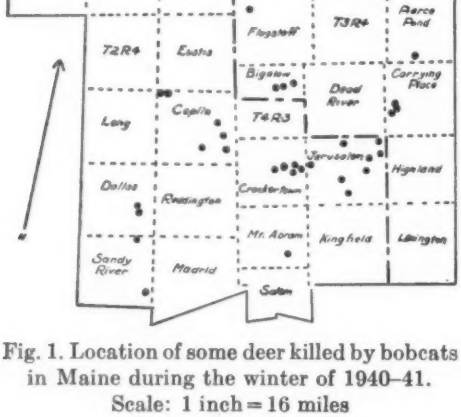

Fig. 1. Location of some deer killed by bobcats in Maine during the winter of 1940–41. Scale: 1 inch = 16 miles

Observations reported below show that deer losses are more frequent than is commonly thought. During the winters of 1939–40 and 1940–41, in conjunction with a study of winter deer behavior, I had many opportunities to observe the winter habits of bobcats in relation to deer in a section of Maine where deer are abundant and the cats are at least common, namely, northern Franklin and western Somerset counties. The State Game Wardens there are intensely interested in the problem and helped to locate bobcat tracks and deer kills, finding, in fact, more kills than the writer was able to visit. These men, Wardens of Division L, first brought the matter to my attention and I wish to acknowledge the valuable aid given by Chief Warden Roy Gray and Deputies Earland Winter, Helon N. Taylor, Norman Buck, Frank Phillips, and Alston Robinson.

Winter Habits

The bobcat travels, hunts, and kills mostly during the night. Morning usually finds it snugly ensconced in a hole or cave, or curled up in a thicket or

[1] A contribution of the Maine Cooperative Wildlife Research Unit, Orono, Maine: Maine Department of Inland Fisheries and Game, University of Maine, American Wildlife Institute, and U.S. Fish and Wildlife Service.

perhaps on a sunny knoll. Each appears to know many hiding places in ledges, under large boulders, and under the roots of old blown-down trees, and will rarely pass such places when traveling unhurriedly without going to examine them. The bobcats in this study habitually hunted and killed at night, with one notable exception. On March 11, 1940, in Jerusalem Township near Big Poplar Mountain, one was "jumped" at about 3:00 p.m. from the carcass of a freshly killed deer, the third animal this cat had killed in traveling not more han half a mile.

The older and larger bobcats seem to be solitary, but the young often travel in groups of two or three. Twice in the winter of 1940–41 groups of three young were located and on another occasion two were found traveling together. Seton (1937) says, "Game Warden F. J. Durgin of Somerset County, Maine reports having seen the tracks of eleven Wild Cats in one drove, and says it is a common thing to see three, four or even six at one time."

Bobcats range widely in their hunting when traveling conditions are suitable. In Brackett Brook Valley, Crocker Township, there was seen the track of a fairly large bobcat whose foot had been injured so as to leave spots of blood in the trail. On March 5, 1941, its trail was followed nearly to the top of Sugarloaf Mountain and thence down into Rapid Stream Valley which is in Mt. Abram Township, five miles from where the track was first found. On March 11 this cat was again found in Brackett Brook Valley, and on March 24 what was believed to be the same animal was shot on Little Poplar Hill, Jerusalem Township, 6¾ miles away in a straight line and much farther the way a bobcat would travel. It had a hole in one foot, probably caused by snagging. Within a month this individual had been located at three different points forming a triangle the sides of which totalled about 18 miles. The smallest circle to include all three points had a circumference of nearly 23 miles. If, as later suggested, cats travel in circles the figures indicate that this cat covered a territory of more than 40 square miles. There could have been two bobcats with bleeding feet, but the track was not seen again after this cat was shot. Constant contact with wet snow and crust probably prevented the wound from healing.

Seton (1937) suggests that bobcats range much more widely during the breeding season than at other times. He gives late February and early March as that season in the northern part of their range. Possibly this accounts for the wide range of the cat just mentioned. Grinnell, Dixon, and Linsdale (1937) report that C. C. Cummings thinks that the bobcat travels in circles much as does a mountain lion except that the former covers a much smaller area, going four or five miles in a night. In the same work his statement is corroborated by W. H. Parkinson, who believed that the bobcat covers an area four or five miles across, and that, "while on his circuit the cat stays in the same resting places that were used on previous rounds."

Regularity in the movements of the bobcat was sometimes suggested in the present study. In Hammond Valley, Jerusalem Township, tracks of a cat were found three different times, at nearly regular intervals of two and one-half weeks, always going in the same

direction, and all three crossed the trail within seventy-five feet of each other. These observations were not continued long enough to prove definitely the usual interval between visits or that the same route is always regularly used. The latter theory is the basis for the general practice of experienced trappers; upon finding a cat track for the first time in a certain place they will not put a trap there, but after having seen a track for the second or third time in one place they will set a trap, feeling sure that the cat will return.

FOOD HABITS

Hamilton and Hunter (1939) record the following fall and winter foods taken from the stomachs of Vermont bobcats, in decreasing order of percentage by bulk: deer (19.32%), mice, varying hares, cottontail rabbits, porcupines, squirrels, grouse, shrews, muskrats, carrion, blue jays, red foxes, gray foxes, grass, poultry, fish, mink, and insects.

Dearborn (1932) lists the food of the wildcat in Montmorency County, Michigan, in 1931, "as indicated by the analysis of more than 300 feces." These were collected in summer but, as pointed out, some may have been six months old. Varying hares comprised 89.6 per cent of this material, and only 3.5 per cent was composed of deer remains. More recent studies of the food habits of Michigan bobcats, reported by Stebler (1940), showed small mammals in 38 per cent of the stomachs examined, hares and rabbits in 36 per cent, remains of deer in 24 per cent, bird remains in 10 per cent, and grouse remains in only 4 per cent. Grinnell, Dixon, and Linsdale (1937) report results of examining 257 wildcat stomachs from California. Game species were found in 78 of these stomachs, distributed as follows: quail in 33, deer in 18, brush rabbits in 13, gray squirrels in seven, cottontails in five, grouse in two.

The stomachs of ten Maine bobcats, taken during the winter, have been analyzed during the present study, two by the author and the other eight by the Food Habits Research Laboratories of the Fish and Wildlife Service at Denver, Colorado. Of the ten, six contained deer meat, one varying hare, one carrion (fat and paper), and two were empty. These limited data suggest that deer meat is important in the winter diet of Maine bobcats.

HUNTING HABITS

Bobcats hunt stealthily, walking slowly and taking advantage of cover and varied topography. They are fond of hunting in country with irregularities in the terrain which permit them to approach unseen to a point of vantage where they can get a good view. By following trails made by them while hunting, one finds where they steal slowly and cautiously up the leeward side of a knoll, stop and peer over the top, then quicken their pace down the other side.

It appears frequently that a bobcat starting on a night hunt will often first spend some time trying to catch a snowshoe hare, hunting carefully through thickets and occasionally working up close enough to pounce. I did not see where a cat had killed a hare, though tracks were found several times which showed where one had leaped and missed its prey. In several instances the tracks showed that the cat had stopped hunting hares after failing in one or two attempts and proceeded to deer yards

either to hunt deer or to feed from a previously killed carcass. Warden H. N. Taylor, who has been on the Maine warden force for ten years and has been a Maine woodsman practically all his life, states that on March 16, 1941, he saw for the first time where a bobcat had killed a hare.

It is believed that a deer is usually attacked while lying down. The cat creeps close enough so that it can reach the deer in one or two jumps. When successful, the cat lands on the deer's back or neck, reaches in under the throat, and fastens its canine teeth in the jugular. Often the deer succumbs immediately and will be found just outside its bed. Sometimes it will be able to rise and run for some distance, carrying the cat on its back. Usually the deer is found within fifty or sixty feet of where the cat had pounced upon it. In some cases it was impossible to find where the cat had attacked and in these instances it probably rode the deer much farther.

Grinnell, Dixon, and Linsdale (1937) quote an instance reported to H. E. Wilder by Dwight Felt of Ruth, Trinity County, California: "Once a wildcat was seen to kill a deer by jumping on the animal's back, clinging there, and biting into the jugular vein." Young (1938) states that he observed tracks in about eight inches of snow showing where a yearling deer estimated to weigh 100 pounds was brought down in about 50 feet by a bobcat which attacked its throat. The cat then ate from the hind quarters and covered the carcass, except the head, with snow.

Attacks are not always successful. Tracks often showed where a deer detected the presence of a cat, leaped from its bed, and ran in time to save itself. In such cases I never saw evidence that the cat has followed the deer for more than one or two jumps. In one instance a handful of hair and a little blood was found suggesting that the cat had reached the deer with its claws but slipped off. By running under a heavy, low-hanging branch or a tree that has been blown over and scraping the cat off, a deer is occasionally thought to escape even after the cat is well mounted. I have not seen such evidence of this but it was reported by the wardens.

Anyone who has observed many deer killed by bobcats can tell from a brief examination of a deer carcass whether or not it is the result of their work. The deer is usually lying on its side with its neck twisted back in a peculiar position, and the head often turned to one side. The deer seemingly dies while trying to get its throat as far away from the cat's teeth as possible. Another quick clue noted is blood on the snow or on the ground beneath the deer's throat. For further proof skin out or shave the throat with a sharp knife; if killed by a cat, two small tooth holes will be found on either side of the throat. Newsom (1930) reports an examination which he made of a Maine deer killed by a bobcat: "At first we were unable to tell where the bobcat had seized the deer, but, on further examination, one small drop of blood fell from the throat and we found where the cat had bitten through the windpipe high up in the neck. The neck was not broken. The cat had made no attempt to eat the meat, and there were very few tracks around the carcass." Only one case was observed where death was caused by other than a throat attack. On March 11, 1940, a cat was shot on Little Poplar Mountain, Jerusalem Township, and

by following its track backward a small male fawn was located. No marks were found on its throat, but the back had been broken in the lumbar region. The large and powerful cat weighed more than 40 pounds, and its canine teeth were blunted and broken.

It seems that bobcats exhibit individuality in the number of deer they kill, and some probably kill more for the love of killing than because they are hungry. Newsom (1930) writes of finding two deer in the vincinity of Ashland, Maine, killed in succession by the same cat, within 150 yards of each other. It is definitely known, from the present study as previously mentioned, that one cat killed three deer in going a half mile. The kills included a medium-sized buck, buck fawn, and doe bearing a fawn. This cat therefore destroyed four deer in less than 24 hours. In another case it is reasonably certain that a cat killed four deer in not more than two or three days. The weather had included a period of thawing, then a day and night of freeze, followed by a snowstorm. The cat killed a large buck during the thaw as was evidenced by the way the deer slumped while running with the cat on him. Also this deer was found in an odd position, lying belly down with its legs beneath deep in the the snow. In addition three more deer, a medium-sized doe carrying a fawn, a yearling doe, and another large buck, were found which had been killed between the freeze-up and the snowstorm. All were within one and one-half miles of each other, the two does not more than 50 yards apart. It is apparent that these instances are exceptional for if they occurred regularly the deer population in bobcat country would be seriously reduced in a short time.

Little is known of a definite nature as to the effect of weather on the hunting habits of bobcats. An impression was formed that windy nights are especially favorable to cats for stalking deer. They seem to hunt more actively then and deer are more easily approached when the wind is blowing. This may be contrary to the beliefs of some persons, but the writer once approached within 25 yards of eight separate deer within an hour on a day when there was a high wind. On many previous trips to the same locality only four deer were seen although many were jumped.

It might appear that deer would be in greater danger from bobcats during periods of difficult travel, and that a cat would make its kill by running down the deer in deep snow, but this is evidently not the usual method of hunting. The benefit to a cat from deep snow is the concentration of the deer population in yarding areas, where they may be found more readily and with less hunting.

Good traveling conditions make bobcats even more destructive because they can cover more territory and thus increase the chance of locating prey. Furthermore, they are not forced to remain in one place long enough to fully utilize a kill. It seems reasonable to believe that if more meat is eaten from each carcass, fewer kills will be required to satisfy the predator.

The principle of "education of the prey" may also be important in this connection, for when conditions are good the cat is able to move from place to place and thus work more frequently on deer that have not been recently frightened. It is not suggested that a deer can be permanently educated to any great degree, for as Leopold (1937)

states, " . . . 'education' of the 'sucker list,' for instance, is of no avail if there be not ample escape coverts." It is difficult to conceive of a type of cover which would afford the deer good protection against bobcats, for the kills are found in all kinds of situations and cats are more at home in thick growth than are deer. It is believed, however, that when a bobcat hunts a deer yard, especially if it misses one or two kills, the deer become excitable and alert, remaining on their feet and moving about. Thus it seems likely that a cat has a better chance of success in a yard or section of a yard that it has just entered.

Easy traveling also enables the bobcat to escape hunters for it is able to make nightly hunts and reach safety in ledges before a dog can be put on its trail.

UTILIZATION OF KILLS

There is indication that cats also show some individuality in taking meat from their kills, that is, in feeding from the different parts of the body. At least one cat whose work was examined had the habit of eating from the forequarter and ribs of its victim. After removing the meat from back of the shoulder and the ribs it broke three or four ribs, opened the thoracic cavity, and ate part of the lungs. Five such cases were found in Poplar Stream Swamp in the winter of 1939–40 and one in Hammond Valley in the winter of 1940–41. Others, and probably most individuals, prefer to make their meal from the hind quarters. In about half the cases the tail was missing from the deer.

Bobcats undoubtedly waste considerable meat when they kill deer, as carcasses are found with varying amounts of meat remaining. From some the cats have eaten one meal only and of others nothing is left but bones and hair. It is believed that they generally return to a kill even though they may not feed on it a second time. Sometimes a cat will make a sort of "tour of inspection," going to as many as four old kills in one night; it may eat a meal from one of them, generally the last visited, or may eat only a small quantity of meat or none at all. Usually it will dig out the remains and cover it again with snow and the scattered deer hair. Tracks indicated that the cats hunted diligently while going from one kill to another.

Whether a bobcat will eventually consume an entire carcass is difficult to determine; it is unjustifiable to blame the cat for not returning to, and eating from a carcass that has been examined by human beings. Carcases have been found that have laid for two weeks with very little meat taken from them. It has been suggested that bobcats find frozen meat difficult to eat and, therefore, that they persist in making fresh kills. In support of this theory it is generally noted that where a carcass is almost entirely eaten the feeding is done within a few days after the kill is made, the cat staying nearby. Warden Alston Robinson has the impression that they will return to frozen kills in the spring and eat some meat after it thaws, but apparently bobcats find carrion distasteful and prefer fresh meat. In one instance a cat dug out a putrified deer carcass but covered it again without eating.

Other animals are known to eat from deer killed by bobcats. Foxes do so to a considerable extent and I have seen tracks indicating that a cat returned to a kill, found a fox feeding there and

drove it away. On the side of Mt. Abram a fisher and two or three foxes had been eating from a cat kill and had almost entirely consumed the deer. During the winter Canada jays also feed from deer carcasses and crows begin eating from them as soon as they return in the spring.

TABLE 1
DEER KILLED BY BOBCATS IN MAINE, WINTER OF 1940–41

No.	*Sex*	*Estimated age, years*	*Estimated weight*
1	♀	1	75
2	♀	3	120
3	♀	2	100
4	♂	1	80
5	♂	2	100
6	♀	3	135
7	♂	4	170
8	♂	1	70
9	♂	3	135
10	♂	1	—
11	♀	2	100
12	♀	3	125
13	♂	3	125
14	♂	5	180
15	♂	3	160
16	♂	3	160
17	♀	1	70
18	♂	3	160
19	—	1	—
20	♂	2	—
21	♂	1	—
22	♀	3	—
23	—	3	100
24	♂	1	—
25	♂	2+	—
26	♂	—	—
27	—	2	—
28	—	fawn	—
29	♀	—	—
30	♂	2+	—
31	♂	2+	—
32	♂	2+	—
33	♀	—	—
34	♂	2	—
35	—	2	—
36	—	3	—
37	—	2	—

The feeding activities of bobcats are affected by weather conditions and snow, especially the latter. When loose snow not more than six inches deep lies on the ground or over a crust strong enough to support bobcats, they easily travel long distances. Then they do not use resting cover near their kills, but after eating will travel several miles to find security in ledges. When traveling conditions are satisfactory they are more likely to frequent higher land and hunt hares in the scrub growth on mountains. The cats probably have more success catching the hares with conditions of light snow because they are much less adapted for running in deep snow than the hares. In deep snow the cats have a somewhat different pattern of behavior; their paws may spread to give them support, but not enough to serve in loose snow. I once saw a cat pursued by a hound in about ten inches of loose snow. Its progress was a slow, tired walk, with its belly dragging in snow all the way. The dog was able to overtake the cat six minutes after it was jumped.

This difficulty in traveling brings about a fuller utilization of the meat of deer that are killed; when there is "hard going" a cat does not range widely but usually remains in the vicinity of its latest kill, eating from it until the traveling is better or the carcass has been fully utilized. On March 11, 1940, on the side of Poplar Mountain, Jerusalem Township, tracks showed where a large cat had killed a small fawn (the instance previously mentioned) and had remained in the immediate vicinity to feed from it for an estimated three days. The cat had laid down in the open within 20 feet of the carcass. There was then about eight inches of loose snow. On March 11, 1941, in Brackett Brook Valley, Jerusalem Township, a bobcat was trailed to a kill made two nights previously. It had returned to feed again on the night before the kill was found and was jumped from a thicket on a low knoll less than 200 yards away. The loose snow was about eight inches deep.

On March 18, 1941, a deer carcass was found in Hammond Valley, Jerusalem Township, definitely killed since a two-foot fall of loose snow on March 12 and more than half devoured, all flesh being gone from the neck and right

side. While eating all this meat the cat denned about a hundred yards away from the kill in the roots of a blow-down tree. It left the vicinity of the kill on the night of March 17 on a crust formed by freezing rain and sleet which fell during the day. It returned to the valley the following night and hunted deer again; it did not return to this kill. Whether this cat was successful in hunting on that night is not known, but it jumped at least two deer, clawing out hair and drawing blood from one.

SIZE OF BOBCATS AND AGE OF DEER

It is a popular belief, reasonable from cursory thought, that only a few of the older and larger cats are able to kill deer; also that only the smaller or weaker deer are taken. There are characteristics of the smaller cats, however, indicating that they are fully as dangerous as the larger ones. In difficult snow conditions they can travel more easily than the larger individuals because they are lighter and do not sink in so deeply, giving them more chances to make kills. They are possibly better able to kill because their teeth are in much better condition. Old cats are more likely to have blunted and broken teeth. I have seen a large buck, estimated to weigh between 175 and 200 pounds, in Poplar Stream Swamp, Jerusalem Township, certainly killed by a bobcat, but the only track anywhere near the kill was that of a small cat probably not more than 20 or 25 pounds in weight. Warden Helon Taylor said that he shot a bobcat of only 24 pounds after it had killed a deer estimated to weigh 200 pounds. Warden E. S. Winter gave an account of a medium-sized deer killed in Hammond Valley, Jerusalem Township, by a small bobcat; the latter's track was seen several times near the kill and was no larger than that of a good-sized housecat.

Of 34 deer killed by bobcats during the winter of 1940–41, 25 were two years old or more, 8 were yearlings, and one was a fawn, in those cases where the age was determined approximately. The cats are not limited to killing females weakened by pregnancy, because of 30 victims that were sexed, 20 were bucks and 10 were does. This sex ratio is very nearly that in the deer legally killed by hunters in the region, 70 per cent of bucks. These facts indicate that cats can take deer as they come and are able to kill one as easily as another provided they can approach near enough to make the attack.

EFFECT OF BOBCAT KILLS ON DEER HERDS

Several difficulties prevent the obtaining of good quantitative information on the effect of bobcats on deer herds. Tracking conditions are not continually good enough to enable one to learn all of a single cat's activities throughout a winter. Even if they were, it would probably be impossible to follow a single track without getting diverted to others. It is difficult to get an accurate census of bobcats because of the wide range of an individual cat and the fact that several may use the same range. It is impossible, economically if not physically, to find all the deer killed, even on the territory of one bobcat, which in most cases would overlap that of others. Moreover, it is impossible to know what percentage of the kills are found. One person may spend weeks traveling at random in the woods without finding a single deer carcass. In the snow with perhaps

no more than the head or a foot sticking out, they are not very likely to catch the eye. I once passed within twenty feet of a carcass in an open growth without seeing it, and upon locating it a few minutes later by following the cat's track was astonished to see my own tracks nearby. The only practical way to find these kills is to follow to the end each wildcat track that is located. Even when trailing a cat one seldom finds the kill until within a few feet of it and then the most evident signs are often the marks in the snow made in covering up the carcass.

There are often periods of a week or more when tracking is impossible because of heavy crusts. One cannot know how many deer are killed during these periods, because the only chance of finding any of them is that a cat may return to some when tracking conditions are suitable. When several cats are working in a region it is impossible for one man to know what all are doing. The alternative is a large field crew, which is expensive.

Of the 18 kills found during the winter of 1939–40, 10 were in Jerusalem Township where, according to estimates by wardens, about 450 deer winter. This loss of only one deer in 45, or 2.2 per cent does not appear to be very serious. Nine of these, however, were in a large yarding area estimated to contain 200 deer, the most intensively studied part of the township, a kill of 4.5 per cent on about four square miles. It is not likely, however, that all the dead deer on this area were found.

During the winter of 1940–41, 37 deer killed by bobcats were found. In Franklin County, six were on Coplin Plantation, five on Crockertown, eight in Jerusalem Township, one in Mt. Abram Township, two in Dallas Township, two on Sandy River Plantation, four on Coburn Gore, and one on Massachusetts Gore. In Somerset County three kills were found on Bigelow Plantation, one on Flagstaff Plantation, one on Pierce Pond Township, and three on Carrying Place Township. The largest kill was in Jerusalem Township, probably because more study was made there than elsewhere.

The six killed on Coplin Plantation were all in a yarding area estimated by Warden Helon Taylor to contain 150 deer, a 4 per cent kill on more than eight square miles found in five days of searching.

SUGGESTIONS FOR FURTHER STUDIES AND MANAGEMENT

A more intensive study should be made to determine, if possible, the quantitative effect of bobcat predation. It would also be desirable to learn the population ratio of deer to bobcats that can be tolerated without predation becoming excessive. At present this type of research is probably too intensive for a state with so much game range as in Maine. A food habits study could easily be managed by requiring that bobcat stomachs be turned in with bounty claims, and correlated with studies on predation and habits of bobcats. The resulting data would provide an interesting index for states where only food analysis work has been done.

Sound management and predator control policies should be based on definite quantitative data. The limited information in this report shows that control is both justifiable and necessary. The bounty system now effective in

Maine pays $15 for each bobcat killed. It is not certain that this payment results in sufficient control in all parts of the State, but it seems unnecessary to make a state-wide increase in the bounty. There is always the alternative of paid hunters, but personal experience in hunting cats leads the author to question whether a paid hunter could produce sufficient results under all conditions to warrant a full-time salary. An effort to popularize bobcat hunting as a sport might be helpful.

SUMMARY

The results of food habit studies on the bobcat over the United States are somewhat confusing; New England studies indicate that deer meat is an important food, and more may be obtained by direct predation than has been thought likely. The toll is not limited to young or weak individuals; some cats perhaps kill wantonly more deer than they can utilize.

The bobcat ranges widely in hunting and uses several different resting places; one may cover a territory of more than 40 square miles. It hunts mostly at night, approaches deer stealthily, makes a surprise attack, and in nearly all cases kills by biting the throat of the deer.

The bobcat is more dangerous to deer during periods of easy traveling, although with deep snow and difficult traveling the deer herds are more concentrated.

Generally the bobcat does not eat all of a kill, utilizing it more thoroughly when bad traveling conditions force the cat to remain near a carcass for several days.

Smaller bobcats are fully as harmful to deer as larger ones. Bobcats are not selective in hunting; ordinarily they kill any deer they are able to approach.

Definite quantitative information on the amount of damage inflicted is difficult to obtain, but the number of kills found indicates it to be considerable in some localities.

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CACHING AND RECOVERY OF FOOD BY THE WESTERN FOX SQUIRREL

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Caching of seeds by rodents for future food supplies is recognized by wildlife managers, foresters, nurserymen, and others to be important in plant reproduction. If the entire crop is consumed, reproduction is prevented but if the crop is stored though not all used by the rodent harvesters, plant reproduction may be encouraged by the seed being protected through the winter from normal exposure to severe climatic conditions (Shaw, 1936). Olmsted (1937) has pointed out that, in Connecticut, "black oak (*Quercus velutina*) invades many communities through burial of its acorns by squirrels." More knowledge is needed of the caching habit and its effect on forest and other vegetation.

Of the many forest-dwelling rodents, probably none is of greater significance to their environment than the larger tree squirrels. Red squirrels and most small ground-dwelling rodents gather many seeds into relatively few hoards, but the larger squirrels make many caches, each of one or a few nuts. This wide scattering and planting, if in suitable seed-beds, may at times be a desirable factor in perpetuating the forest. These squirrels, however, need large quantities of food to sustain them, especially as they do not hibernate through the long winters. They depend heavily on the fruit of commercially important hardwood species such as oaks, hickories, walnuts, beech and formerly, the American chestnut. The rapidity with which these nut crops are cleaned up from the forest floor is almost phenomenal. Hahn (1908) describes the "disappearance" of a very large acorn crop on the Farm of the University of Indiana in the autumn of 1906, when gray squirrels were also very abundant. He "estimated that each of the large white oaks produced from two to eight thousand acorns during that season. Eighty acres [were] heavily wooded with white oaks and nearly a hundred acres more [had] a considerable growth of these trees. Before November 1, the immense crop of acorns had been so completely garnered by the squirrels that none were in sight on top of the leaves and only an occasional one could be found by the most careful search." In the long run, the fate of the seed crops controls that of the forest.

In the fall of 1928 I studied the life history of the western fox squirrel (*Sciurus niger rufiventer*), a major objective being to determine, if possible, the effect of this species on forest reproduction. This investigation was a part of the program of a junior instructorship which continued through the following spring under the School of Forestry and Conservation, University of Michigan.

I am grateful to Dean S. T. Dana and Alvin G. Whitney for arranging the financial assistance that made possible this year of study and field work and to Professors Whitney, H. M. Wight and L. R. Dice for advice and suggestions on this project.

Two studies on caching and recovery of nuts to determine the percentage and method of removal from hiding places, were made in Forest Hills Cemetery in Ann Arbor. The squirrels were accus-

tomed to the presence of people, but were not as tame as many squirrels in city parks, so that many records were made that would have been practically impossible in woodlands open to hunting where the squirrels were wild. The third study comprised experiments on captive squirrels in the University of Michigan laboratories.

MISCELLANEOUS OBSERVATIONS

The act of caching follows a set routine. The squirrel picks up its food between the incisors and rears on its haunches. With aid of the forepaws the animal revolves the nut once or twice between its teeth, possibly to test for soundness or palatability. A nearby spot is then selected and a shallow hole is dug with the front paws. The nut is deposited in the hole with the mouth and, before the grip of the incisors is relaxed, is vigorously "set" or tamped into place by two or three pumping motions of the whole body. Loose dirt is then moved into the hole by the paws and patted down level. Part of the nut may still be exposed, but bits of grass, leaves and other loose debris are swept over it, thus restoring a normal appearance to the spot.

The instinct to hide surplus food appears early in the fox squirrel. Two broods of young were born to captive animals in the University of Michigan laboratory. One young, 75 days old, cached an acorn in the straw litter in the corner cage by a much abbreviated series of the movements used by adults. This act of storage was probably performed to get the food away from another and meddlesome member of the brood.

In natural forests, fox squirrels are probably spaced sufficiently apart by food and other environmental limitations so that direct competition occurs only where ranges of individuals join. Even in the relatively crowded squirrel population of the Ann Arbor cemetery, the animals rarely showed signs of conflict while pursuing their autumn storage activities. Indeed, it was necessary for two squirrels to almost stumble over each other in their absorbed hunt for nuts before showing irritation. Once the caches were made, however, individual proprietary rights in them seemed to be treated lightly.

The apparent transitory interest in stored food was observed once in the laboratory. One of two males caged together found or dug up an acorn from a previous cache, which he jealously guarded from the other. After about five minutes, during which the proprietor of the acorn fiercely repelled any advance of his cage mate, as well as giving me a couple of vigorous scoldings, he cached it in the floor litter. Several minutes later the other male dug up the acorn and ate it, while the former owner gave not the slightest sign of interest.

Whether squirrels recognize their own individual caches is an open question. In two instances I saw a squirrel, intently searching over the ground, come to a nut that had been previously cached but only partly buried. The animal tensed preliminary to leaping upon it, then obviously relaxed, hopped to the nut, gave it a couple of pats with the front paws, and turned away. I inferred from the general appearance of the squirrel that it was the same one seen to cache the nut on the previous day. His actions on discovery (or re-discovery) of the cache may have been either recog-

nition of "property" or acceptance of storage which, regardless of ownership, should be protected or respected.

Fox squirrels have been known to transfer cached nuts from their original hiding places. Kennicott (1857, pp. 59–60) cites a reliable observer in Illinois who watched a squirrel carry large numbers of nuts from storage in the deeply snow-covered ground to new caches in the forks of small trees. Frost (1913) described the actions of a gray squirrel in Connecticut that reclaimed eight nuts from individual caches and reburied them under leaves in one place about 15 or 20 feet distant. Each nut was unerringly detected under untracked two-inch snow, and the whole task was performed in a most business-like manner in less than 10 minutes.

During the fall nut-gathering season of 1928 I discovered several times that hickory nuts had been taken from freshly made caches previously marked by me. Plenty of food remained on the ground, so I assumed that most of the nuts were re-cached. In one instance, in my haste to mark the spot accurately, I had frightened the animal away before it had opportunity to cover the nut completely. In other instances there had been no interference except such as was necessary to locate and stake the cache after the squirrel had left. On March 12, 1929, a pignut recorded during the previous autumn was dug up and re-cached about 20 inches away while I watched, and a white-oak acorn had been removed from its very shallow depression sometime during the previous three days. Fox squirrel tracks were distinct in the surrounding mud. The acorn had started to sprout, splitting the shell into two parts. The squirrel had eaten a small amount of meat from the growing tip, nibbling between the halves of the shell, and then had replaced the acorn in the same spot. The capacity for growth of this nut was destroyed.

If food is surplus to current needs, the large tree squirrels may cache during any month of the year, but most of the storing occurs in the cooler season. Seton (1921) recorded a gray squirrel (*S. carolinensis*) in the National Zoological Park at Washington, D. C., that cached a nut on January 23. I saw fox squirrels in the wild at Ann Arbor caching on the following dates: December 31, March 6, 12, and 17, and April 23 and 26 (Cahalane, 1930). Captive fox squirrels that had been caged indoors for practically their entire lives regularly concealed surplus food through the winter months during which they were observed. Other captives that had been live-trapped in January as adults were never seen to cache excess food until early in the following March and then the practice was rare (*ibid.*).

The number of nuts cached by squirrels must, in the aggregate, be very large. Seton (1928) expresses the belief that "there can be little doubt that one squirrel will hide literally thousands of nuts; and a thousand nuts, if he can recover them, are a fair supply for a year." He watched a fox squirrel bury ten peanuts during an hour in a city park in Madison, Wisconsin, after which the squirrel seemed weary. It is my impression that this is not a high rate for the caching performance, although Seton's observations were made on August 1, very early in the season and before the instinct may be strongest. After a hard frost when fallen nuts were plentiful, on October 11, I watched a fox squirrel

caching hickory nuts in the cemetery at Ann Arbor. The animal buried four in seven minutes, during which he was out of view for about two minutes.

Seton (1928) seems to imply that only a fraction of the autumn harvest is recovered. Dice (1927) also says that "squirrel undoubtedly fail to find many nuts they have buried." Systematic experiments, described later in this paper, cast some doubt on these opinions. General observations, also, indicate that the cache-finding faculties are exceedingly well developed.

Fox squirrels at Ann Arbor apparently experienced no difficulty in locating nuts and acorns buried under about six inches of solidly packed and frozen snow. The snow made it easy to read the record of their searches without actually observing them. Their tunnels ran almost straight down, and were only large enough to admit the head and forequarters of the animal. In nearly every instance, the "cast" of a nut or acorn in the frozen ground directly in the center of the excavation proved the accuracy of location by the squirrels.

On February 4, I watched a fox squirrel digging in the hard, crusted snow; it was not disturbed by my presence, but left before reaching food. On completing the digging, I found a pair of acorn "cups." One is tempted to infer that the squirrel had been able to determine, while still an inch away from the objective, that it was not edible. The same day I found another uncompleted excavation, and upon digging down to the gound, found an acorn. The squirrel had been digging in exactly the correct direction, but perhaps had been disturbed or had become weary before reaching the food. Clearly, sight was of no assistance as a guide to these animals in locating food buried under snow. Memory would hardly serve better, unless the changes in appearance of the surface by snow is much less confusing to squirrels than to man. The incident of the acorn "cups" indicates that the squirrel was guided in digging by a factor common to both food and the "cups," which might be odor. Extraordinary perception, however, would be needed for the animal to tell the difference through about an inch of frozen snow. W. L. McAtee informs me that about 1905 to 1910 he had ample opportunity for observing grey squirrels from a window of a laboratory in the Department of Agriculture grounds at Washington, D. C. During one winter a crusted snow covered the lawn with a uniform sheet of white, but the squirrels knew the exact places to dig down and get nuts. Numerous successes and no failure in this marvelous activity were observed.

ABILITY IN RECOVERING CACHES

The major objective of my observations in the cemetery was to determine the percentage of cached nuts recovered by fox squirrels. The level area of this property lay in the angle formed by Geddes Avenue and Observatory Street, almost completely shaded by oaks and hickories, mostly of bearing age, many being fine old trees. The cemetery was well cared for, with clipped lawns covering the lots. After the autumn leaves had begun to drop in quantity, raking ceased and debris accumulated as a mulch to protect the grass and ornamental plants until growth started in spring. It thus was possible to record

and mark the site of observations with reasonable expectation that they would be free from human molestation during the fall and winter.

Fox squirrels were abundant in the cemetery and were busily caching nuts when my field work started on October 13. They were fairly tame and most of them permitted observation from as close as 25 to 30 feet. The oaks and hickories fruited prolifically and the squirrels were industrious, so that, with some patience it was possible to observe and record many caches of individual acorns or hickory nuts within a few hours of suitable weather.

My procedure was simple. A fairly confiding squirrel was followed and carefully watched. As soon as a cache was completed it was definitely located, a numbered wooden greenhouse stake driven into the ground at a prescribed distance and direction from the cache, and records made in my notes and on a detailed plan of the grounds. In most cases, the stake was set at a distance of one inch. Because of the possibility that such close intrusion might be resented by the owners, many stakes were placed six inches away from the nuts. Each stake was about ½-inch wide, by ⅛-inch thick; when placed it protruded about ½-inch above ground. The notes and numbered markers made it possible to relocate most of the caches in the late winter or early spring and thus to learn if the contents had been removed.

Neither the small markers nor larger temporary ones seemed to have any significance to the squirrels. Several times I watched animals busily caching nuts as they chanced to return to spots where they had buried food a few hours before. Close to the hidden store I had set temporary markers to serve until permanently numbered stakes could be driven and notes made. The squirrels seldom noticed these marker pegs, about 4 inches high. In one instance an animal, seemingly absorbed in its hunt for food, had the stake brought forcibly to attention by running into and almost upsetting over it. Nevertheless, after examining the intruding landmark, no move was made to disinter the cached nut.

A number of earlier caches were found while searching for nuts that the squirrels were seen to have buried, and these were added to the record.

After making a cache, the squirrel would ordinarily hop away a number of feet before searching for another nut. Possibly this was a mechanical routine to avoid attracting the attention of other squirrels that might be disposed to rob the cache. In any event, this movement enabled me to walk quietly up to the freshly-planted nut and to go through the recording procedure without unduly hurrying or alarming the squirrel. It was often possible to follow one squirrel for an hour or more and to make a dozen records, before the animal became tired or perhaps annoyed at such persistent surveillance and took to the trees.

The ground was far more compact than in undisturbed woodland, because rolling of the sod, mowing, raking, and other care had resulted in much trampling earlier in the season. This possibly explains why nuts were rarely buried more than a half inch below the surface. In a few cases they were left on top of the ground and scarcely more than sprinkled with a few bits of soil and grass. Frequently a nut was sunk less

than half its diameter below the surface. Sometimes the caching operation consisted merely of a few vigorous tamping motions with the head, which "settled" the nut on the ground, followed by a cursory movement of the front paws to scatter some bits of grass over the "cache." It was possible to locate the planted nuts in well over 50 per cent of the cases observed.

Between October 13 and November 24, 289 cached nuts were staked and recorded, most of them by November 4. About 50 were found accidentally; the remainder were located by watching the squirrels. Of the recorded caches, 38, or 13 per cent, either were destroyed or could not be found at the end of the winter. These losses were all hickory nuts, 24 shagbarks and 14 pignuts. The net usable records were thus reduced to 251, of the following species:

Shagbark hickory	123
Pignut hickory	113
Red oak	1
White oak	10
Black oak	1
Oak (species uncertain)	3
Total	251

As a check on the possibility that the squirrels might dig up many of their caches and eat the nuts or re-bury them elsewhere, I examined about 10 per cent of the caches during November and early December. Only three were found to be empty:

	Recorded	*Found removed*
Shagbark hickory	Oct. 31	Nov. 3
Shagbark hickory	Oct. 15	Nov. 24
White oak	Oct. 15	Dec. 2

On the basis of this random sampling, less than 10 per cent of the original caches were emptied before winter. All caches (except the three just mentioned) were examined near the end of the winter. Checking began on March 10 and proceeded as rapidly as other duties and the season permitted. Most caches had been inspected by April 5, but not until April 23 had the melting of certain snowbanks and thawing of the ground proceeded to where the last few storage places could be examined.

Of the 251 nuts cached in the fall of 1928, whose resting places were definitely determined in the spring of 1929, all but six had been removed by the squirrels at my first spring inspection. Periodic return visits were made to learn if these few remaining nuts would be removed later. Four of the six were subsequently removed and presumably eaten by the squirrels, but the other two were apparently undisturbed until May 8 and 21, respectively. As the germs of at least one had died the experiment was terminated. Because of their special interest, detailed "case histories" for the six long-surviving caches are given:

No. 25. Shagbark hickory nut. Cached October 15, incompletely buried, upper surface level with ground but visible; site inspected March 12, when found undisturbed; empty, when visited again May 7.

No. 61. Pignut. Cached and completely buried in soil, October 21; squirrel seen to remove and re-cache it about 20 inches away, March 12; still in place in new location on April 5; had been taken by May 7.

No. 177. Shagbark hickory nut. Buried ¼″ below ground surface, October 30; undisturbed April 23; also undisturbed on May 7, when rain had washed away sufficient soil to expose the upper end slightly; nut removed between May 7 and May 21.

No. 230. Shagbark hickory nut. Squirrel seen to bury it about ¼″ below the ground, November 4; in place, April 6, again May 7, but removed by May 21.

No. 2. Pignut. Cached 1″ below surface in

soft earth, October 13; examined, April 5, when germinated enough to split shell and expose sprouting kernel; replaced and re-examined, May 8, when dead; nut given to caged squirrel and eaten.

No. 182. Shagbark hickory. Buried about ½", October 31; not disturbed by April 23 or May 7, but somewhat exposed by rain by latter date; still in place May 21, but no signs of imminent sprouting; fed to captive squirrel, and eaten readily.

Thus only two nuts, one of shagbark and one of pignut hickory, or less than one per cent of the recorded autumn cache, survived until May 8 and 21, respectively. The pignut germ had died but that of the shagbark hickory nut may have been capable of growth. The other four, or about one and one-half per cent of the total recorded in the autumn, were not utilized by the squirrels until sometime after March 12, although these nuts were all in the original caches on that date. One nut was taken after April 5, and the remaining two after May 7.

It is significant that of the six long-surviving caches all but one were covered with soil, and half of them were buried ½ to 1 inch below the surface. The only two nuts never found by the squirrels were sunk ½ to 1 inch below the ground level. Of 126 caches recorded as "exposed above ground," only one (0.8 per cent) survived until late spring. Of the caches that lasted until April or May, 1.25 per cent were just under the surface, 5 per cent were buried ¼ inch, 9.5 per cent were buried ½ inch, and 14 per cent were buried 1 inch deep.

Biologists, as well as many other people, have long speculated on the means employed by gray and fox squirrels in finding buried nuts. They have by no means agreed. Merriam (1882–84) wrote that: "Many persons who have observed this [caching] habit in summer regard it as an idle pastime, and question if the squirrel ever finds the nuts again, knowing that he could never remember the exact position of so many. However, his sense of smell is very acute, enabling him to detect the presence of a nut at some little distance; hence, though he does not, of course, remember the exact spot where each one is buried under the leaves, he can, by moving carefully over the ground, discover a great many of them." Seton (1929) states that memory guides the animal back to the general area in which the caches were made, when the sense of smell is brought into play to find precise locations. Burroughs (1905) was convinced that "smell is the guide." Stoner (1918) believes with Kennicott (1857) that "it is not probable that squirrels 'remember' where the morsel has been placed, but probably depend upon a keen sense of smell." Nichols (1927) in April watched a gray squirrel on Long Island, New York, dig up and eat peanuts that had been buried the previous fall or early winter by the same or another animal. "No chance," he observes, "of its remembering where each one had been placed. It worked slowly and carefully about until one had been located, obviously by sense of smell. . . . "

Other biologists, however, have expressed preference for the memory theory. Johnson (1930) states that squirrels "may be guided by memory of location rather than by sense of smell." Frost (1913) made an observation on the gray squirrel that indicates a memory for the location, for the animal "leaped" directly onto nuts concealed

under two inches of undisturbed snow. Experiments on a wild fox squirrel by Dice (1927) determined that this particular individual never found walnuts buried in dry sand and indications were that smell was not employed. He concluded, "If squirrels do not find buried nuts by the sense of smell, the presumption would be that they remember the place where they have buried each nut that they find. This would require a well developed memory though not necessarily a perfect memory, for squirrels undoubtedly fail to find many nuts they have buried."

IMPORTANCE OF MEMORY IN CACHE RECOVERY

Between November 17 and December 2, I placed 264 shagbark and pignut hickory nuts singly on or in the ground, two feet from the corners of a number of stone burial monuments which served as permanent landmarks. Sets of eight nuts were deposited at three depths; from ¾ inch to entirely buried but without covering the top of the nuts with soil; at depths of ½ to 1 inch below the ground level; and completely covered. (Of 244 caches made by squirrels and recorded in the preceding food-recovery study, 126 protruded above the ground level, 70 were completely but thinly covered with soil, 20 were buried ¼ inch, 21 were covered ½ inch, and seven were covered with an inch of soil.)

Small stakes were placed at one inch from a number of the nuts, to ascertain whether, contrary to my observations, the presence of the markers had been an aid to the animals in finding their own caches in the previous experiment.

Leaves were re-scattered over the ground after the nuts were placed, so that even those protruding above the soil were not exposed. To avoid the possibility of attracting the squirrels to the "artificial" caches, only a few were examined before late winter. Checks of remaining nuts were then made at intervals until May 7. By the latter date, other fresh food was abundant and squirrels had practically ceased to hunt for leftover stores. Data on these experimental caches are given in Table 1.

To summarize, 264 hickory nuts were buried in as many locations. About 75 per cent of these caches closely simulated those of squirrels, being hidden by loose leaves and blades of grass but not completely buried in soil. The remainder were buried more deeply than were most nuts stored by the animals. Of 168 nuts cached in November with the upper part above the soil level and covered with ground litter, only two (1.2%) remained in place at the end of April. Of 96 buried so that their tops were ½ to 1 inch beneath the ground surface, 42 (43.8%) remained undiscovered at the end of April or even well into May, when observations ended. Only 8 of these nuts (under 20%) were apparently not viable at the end of the winter. The remainder, therefore, should have retained any qualities of odor or other factors possibly attractive to the squirrels.

As observed in the first study, the markers did not seem to attract the attention of the animals. In this experiment, also, unstaked "caches" were located as readily as those that had been marked.

It is significant that so many of the nuts deeply covered escaped the search of the animals, while practically all surface caches were plundered. One cannot

TABLE 1

RECOVERY BY SQUIRRELS OF NUTS EXPERIMENTALLY CACHED

No. of set	*Species*	*Position in ground*	*Date placed*	*Staked*	*Results*
1	Shagbark Hickory	¾ to level	11–24	Yes	All removed 4–30
2	"	" "	"	"	" " "
3	"	" "	"	"	" " "
4	"	" "	"	No	" " "
5	"	" "	"	"	" " "
6	"	" "	"	"	" " "
7	"	" "	"	"	" " "
8	"	" "	"	"	" " "
9	"	" "	"	"	" " "
10	Pignut Hickory	Level, not covered	11–17	Yes	2 removed 11–24; others gone 4–30
11	"	" "	"	"	" " " 1[a] remaining 4–30
12	"	" "	"	"	3 " " others gone 4–30
13	"	" "	"	No	5 " " " " "
14	"	" "	"	"	4 " " " " "
15	"	" "	"	"	1 " " " " "
16	"	" "	"	Yes	All removed 4–30
17	"	" "	"	"	" " "
18	"	" "	"	"	" " "
19	"	" "	"	No	" " "
20	"	" "	"	"	" " "
21	"	" "	"	"	1[a] remaining 4–30
22	Shagbark Hickory	½ to 1 inch below ground	12–2	Yes	All removed 12–10
23	"	" "	"	"	" " "
24	"	" "	"	"	" " "
25	"	" "	"	"	None removed 12–15; 8[b] remaining 5–7
26	"	" "	"	"	None removed 12–15; 7[c] remaining 5–7
27	"	" "	"	"	None removed 12–15; 7[d] remaining 4–23
28	"	" "	"	No	7[b] remaining 5–7
29	"	" "	"	"	6[d] " "
30	"	" "	"	"	7[b] " "
31	"	" "	"	Yes	All removed 5–7
32	"	" "	"	"	" " "
33	"	" "	"	"	" " "

[a] sound and apparently viable.
[b] 6 sound and apparently viable.
[c] 5 sound and apparently viable.
[d] 4 sound and apparently viable.

conclude, however, that sight is relied upon greatly in looking for food, as during much of the winter, all caches were under several inches to a foot or more of snow.

The fact that 47 per cent of the man-made caches buried from ½ to 1 inch were not located would indicate that memory is used in recovery of food. Some discount of failure should be made, however, as the percentage of man-made caches buried at these lower and more difficult depths was three times as large as those made by squirrels at the same depths. Since the squirrels found 99 per cent of the more lightly-covered man-made burials and 56 per cent of the deeper ones, it is concluded that, while memory may play some part in recovery, it cannot be the major factor.

FURTHER TEST OF ABILITY AND METHOD IN LOCATING CACHES

Experiments were made with two sets of fox squirrels in the laboratory. Two animals (MZ), possibly a pair, were caged in the University Museum of Zoology by Dr. and Mrs. Arthur Svihla, to whom I was indebted for permission to make observations. These squirrels had been captured soon after their eyes were opened, about nine months earlier. Two adult females (FC) were confined in the Forest Zoology Laboratory of the School of Forestry and Conservation. The squirrels had ample room for exercise but were usually fed too well. They had been in captivity for but two or three months and their senses could therefore be considered to be reasonably keen.

The temperature in both rooms was maintained at about 75°F. The floors of the cages were covered with wood shavings and sawdust, so that objects such as nuts could be felt or turned up accidentally by the squirrels in running about. Pans about 17×12×4 inches deep were filled with earth (at room temperature except as noted below), nuts were buried ¼ to ½ inch below the surface, and the pans then placed in the cages. Careful watch was maintained on the animals whenever time permitted.

In summarizing the results of each experiment, a perfect score (100 per cent) was given when all nuts were located accurately on the first trial. Errors in digging were penalized, even though the nuts were eventually located. Obvious uncertainty, fumbling over the surface of the soil, and other signs that the search for food was dependent on chance also lowered the score. A brief description of the series of seventeen observations follows.

1. In earth of average moisture content, 11 hickory nuts and one red oak acorn were buried separately and about ½ inch below the surface. Within five minutes the squirrels (MZ) had found four nuts. They dug down directly from above without making an error and without showing evidence of doubt or hesitation. All of the cached nuts had been removed within 48 hours. Holes, with an impression of the nut remaining at the bottom, showed their accuracy of location. This score may be considered perfect.

2. In earth slightly drier than average, 12 hickory nuts were buried with their upper surfaces ½ inch below the surface; all were gone 24 hours later. The squirrels (MZ) had located all nuts accurately without any evidence of false tries. Score again perfect.

3. Moist soil (4,540 g. of air-dry earth and 300 g. of water) was used to hide 2 acorns and 2 hickory nuts given to the female of the two MZ squirrels. The animal was either surfeited with food or was confused. She pawed lightly over the surface of the soil, in the process kicking out an acorn; then paid no attention to it, so the experiment was closed. The results are difficult to evaluate in this case and no conclusions are drawn.

4. In moist but not muddy soil (3 kg. of air-dry earth and about 160 g. of water) 3 acorns and 3 hickory nuts were placed. The pan was given to the two females (FC). Each animal immediately found a hickory nut, and the other nuts were removed within 8 minutes without errors. Score, perfect.

5. In moist soil, 3 hickory nuts and 3 acorns were cached. The two females

(FC) were not hungry and only the larger animal was active. A half-minute after the pan was placed in the cage, she sniffed about, nosed the earth but did not dig, then shifted to another spot and dug unerringly straight to an acorn. After 22 minutes spent at other interests she located another from the surface without making a mistake. At 28 minutes, after considerable searching with the nose above the soil and one abortive digging, she found a hickory nut. At 30 minutes she missed another by an inch but located it on the second try. The last two nuts were found from the surface without error at 35 and 38 minutes. The score was approximately 67 per cent.

6. To a pan containing 4,540 grams of atmospherically dry (very dusty) earth 600 g. of water was added, making a decidedly muddy mixture. Then 3 acorns and 3 hickory nuts were buried. The squirrels (MZ) were evidently not hungry, but they readily found four of the nuts without errors within the following times from the beginning of the experiments: 45 seconds, 5 minutes, 6.5 minutes, and 13 minutes. The remaining two acorns were removed within an hour. Score again perfect.

7. In very muddy soil (4,540 g. air-dry, about 530 g. of water added) 2 hickory nuts and 2 acorns were buried. After one failure, the MZ female squirrel accurately located a hickory nut in about 30 seconds. Four minutes later she dug directly to an acorn. She nosed lightly over the earth and tried persistently to get under the pan. She then returned to the soil and tunneled directly to a nut. The last nut was accurately located a little later. Results in this case are not conclusive, but the efforts of the squirrel may be termed well-directed and fairly successful. Score about 75 per cent.

8. Four nuts were buried in a pan of muddy soil placed in the MZ cage. Nuts were found as follows: at 30 seconds without an error; 90 seconds, after digging had been a little to one side; 4 minutes following an extensive, haphazard search; 6 minutes, without error. Score about 50 per cent.

9. Four nuts in a pan of muddy soil were given to the two females (FC). Two of the nuts were found within an hour. As the animals did not resume the search, the experiment was closed. Traces in the earth showed that the squirrels had dug in precisely the proper places without error to reach the nuts. Score, perfect.

10. Muddy earth containing 3 acorns and 2 hickory nuts was thoroughly chilled but not frozen. When placed in the MZ cage the squirrels showed confusion and uncertainty by digging lightly over the entire surface. They succeeded in finding two hickory nuts in about 10 minutes, but the search was plainly a blundering one and the experiment was terminated. The score may be considered as zero.

11. Muddy earth containing 3 acorns and 2 hickory nuts was kept at low temperature for two days, almost freezing it, then given to the FC squirrels. The animals were not hungry, but the larger female found two nuts during an hour without error. All nuts had been located without mistake in less than three hours. The perfect score in this case, as contrasted with the failure in the preceding experiment, may possibly be attributable to a greater keenness of sense in the wild-reared than in the captive-reared animals.

12. Soil was dried until, when handled, only dust adhered to the hands, and 6 hickory nuts concealed in a panful of it. One MZ squirrel dug three times before finding a nut; the rest were located without difficulty. Score about 70 per cent.

13. Six nuts were buried in a pan of bone-dry earth, which was given to the MZ squirrels. Both animals investigated the surface. One sniffed thoroughly over the earth, made several strokes at digging in two places, acting in an undecided manner, but desisted. Five minutes later one squirrel returned and dug slowly and uncertainly; it first examined an area where no nuts had been buried, then transferred its search to a spot about 4 inches away and here located an acorn. Score, zero.

14. Six nuts were concealed in absolutely dry earth and placed in the MZ cage. After a brief futile search, one squirrel desisted, while the other nosed and dug uncertainly over almost half of the pan before uncovering a hickory nut, evidently by chance. The other nuts had been found and removed 24 hours later, but evidences pointed to haphazard digging. Score, zero.

15. Eight nuts were buried in a pan of atmospherically dry earth given to the two females (FC). After much of the soil had been turned over, the animals had found all except one (weeviled) acorn within five hours. The undesirable nut had undoubtedly been discarded deliberately. The score of this experiment is also practically zero.

16. Six nuts were cached in air-dry soil in the FC cage. All were undisturbed when I examined them at intervals of 7, 28, and 52 hours after the beginning of the experiment. Seemingly, the animals were unable to detect the presence of anything edible in the dry soil and did not even dig into it. Score, zero.

17. The same six nuts used in experiment 16 were then removed, wrapped individually in cotton batting, and the whole soaked in water. The wet bundles were then reburied in the dust-dry soil, care being used to keep the soil dry so far as possible. Wetting the nuts appeared to make their presence known to the same squirrels (FC) that previously had been so indifferent. Two hickory nuts were found and eaten within an hour, and all but one of the four remaining had been found within seven hours. Most if not all had been located accurately, withour errors. Score, high.

Reduction of this series of observations to statistics is difficult, since so many factors were uncontrolled. Observations could not be continuous, and the conditions under which a number of the caches were recovered by the squirrels were not seen. In other cases evidence of the searches by the squirrels was plain. A rough tabulation can be made, however, from which general deductions may be drawn.

Of the 17 experiments one was discarded as too inconclusive. The soil was of average moisture content in 4 cases, decidedly muddy in 4, chilled mud in 2, and dried to the low humidity of the steam-heated laboratories in 5. In the final trial, moistened nuts were buried in bone-dry soil. In dry soil 32 nuts were cached, in average soil 36, and in muddy earth at room temperature 18. Ten nuts were used in the two experiments with chilled earth and 6 were moistened and buried in dry soil. The number of nuts accurately located

without errors ("successful searches") and those ("errors") found obviously by chance, or only after a haphazard search, or not at all were as follows:

Soil condition	*Number of experiments*	*Total nuts used*	*Successful searches*	*Errors*
Average moist	4	36	34	2
Muddy	4	18	15	3
Chilled mud	2	10	5	5
Dust dry	5	32	5	27
Soil dry, nuts moist	1	6	6	0

It seems safe to conclude that moisture is a necessary factor in the successful search for food. An excess of wetness, however, increases the chances of error. Moisture increases diffusion of odor and this and other indications point to the employment of smell in finding nuts.

If one critically compares the results of attempts by the two sets of squirrels to excavate buried nuts, it becomes apparent that their abilities were not equal. In parallel tests with soil nearly frozen, the females (FC) succeeded when the other two squirrels (MZ) failed completely; in the case of muddy soil the former achieved success when the MZ squirrels were only partially successful. It is significant that the FC squirrels which exhibited the highest ability in discovering these buried nuts were fully grown when live-trapped and had been caged between two and four weeks. The less successful squirrels (MZ), on the other hand, had been removed from the nest some ten months before, when only a few weeks old. They had spent practically their entire lives under artificial conditions. Apparently the senses used in searching out hidden food had, through lack of use, never developed to the extent found in wild-reared squirrels.

CONCLUSIONS

My observations indicate that fox squirrels recover and consume 99 per cent of the nuts they bury. When these animals are abundant, therefore, they may greatly inhibit the reproduction of an oak-hickory forest.

I find it difficult to subscribe to the theory that memory is a major factor in the recovery of food stored by the squirrels. The very large percentage of recovery would require an incredibly prodigious memory if dependent upon that faculty. Memory cannot be of great assistance to these animals when snowfalls change the landscape by filling in hollows and drifting into heaps. Memory is a necessary basis for the sense of ownership, yet the squirrels' interest in possession for that most precious thing, food, is high for only a few moments, and quickly fades.

The factor of memory, however, cannot be eliminated completely from this activity. Following the marking of squirrel-made caches in the autumn, it was found that all except two were removed by the animals during the winter and early spring. At the same time and in the same area, a number of "caches" of nuts planted by me were overlooked.

In looking over earth or through litter for concealed nuts, the caged squirrels very obviously used their sense of smell. The working or wrinkling of the nose could be seen, and continuous sniffing was heard. At such times, so much air was drawn through the nasal passages that dust from the chaff and other litter often caused the animals to sneeze violently and successively. (Dust was frequently raised at other times by play or similar activities, but under

these circumstances, inhalation was not enough to cause sneezing.)

In the experiments with the caged squirrels, the animals were highly successful in accurately locating nuts in moist soil, but nearly always failed in dry soil. Since moisture intensifies odors and dryness reduces them, the sense of smell would appear to be the major factor in recovery.

I therefore believe that memory is of some assistance to squirrels by localizing their field of search, but a highly developed sense of smell is normally used with great accuracy in finding food.

SUMMARY

Caching and recovery of food by the larger tree squirrels is of great importance to reproduction of forest trees and other plants. The account of this activity is a part of a life history study of the western fox squirrel (*Sciurus niger rufiventer*) at Ann Arbor, Michigan, from October 1928 to May 1929. Observations were made on the caching habits of wild squirrels in a heavily-wooded city cemetery and of captive squirrels in the laboratory.

To determine the percentage of recovery, 251 hickory nuts and acorns cached by wild squirrels, were recorded and their locations marked by small stakes. Examination indicated that about ten per cent of the caches had been emptied (utilized or reburied) during November and early December. The caches were rechecked in the spring when all but two were empty and the nut in one of these was non-viable. The fox squirrel thus caches many nuts under conditions ideal for their germination, but practically all are consumed before growth progresses to any extent. When squirrels are abundant, therefore, they may greatly inhibit reproduction of certain favored tree species.

Biologists do not agree on the sense employed by squirrels in relocating stored foods.

To determine whether memory is a large factor in recovery of cached nuts, 264 hickory nuts were experimentally buried during the autumn in as many locations, all carefully recorded, then inspected during late April and May of the following year. Following the squirrels' method, 168 nuts were partly buried in soil and covered with ground litter; only 1.2 per cent remained. Of 96 nuts buried ½ to 1 inch, 43.8 per cent remained. Since 83 per cent of the man-made caches were located, it was concluded that memory is not the major factor in recovery.

Further to test the ability and methods of squirrels in locating hidden food, experiments were conducted with four captive animals by offering nuts buried in earth of differing moisture content. Expected individual differences in ability to detect the food were observed.

The nuts accurately located on first trial by direct tunnelling were, mostly in soil of average moisture content. Very little success was achieved in bone-dry soil. Identifiable errors by the squirrels were extremely few when searching on normal soil, three times as high in muddy soil, and about fifteen times as high in bone-dry soil. As soon as nuts were dampened and placed in the dry soil, success was complete. Since dampness accentuates odors, the results of these experiments (as well as the other observations stated) indicate that the sense of smell is the major factor in finding food.

This extraordinarily developed sense may also explain the phenomenon of locating nuts under snow. Changes of appearance of the terrain due to drifts of snow seem again to reduce the possibility that memory is a large factor. Captive squirrels, reared in the wild, accurately located man-buried nuts in mud which had been chilled to almost freezing point, so it is possible that hunger may sharpen and train their sense of smell to such an extent that they locate nuts through several inches of snow by this means.

Memory cannot be excluded, as all but one marked squirrel-made cache of viable nuts were emptied by their owners, whereas some man-made caches were overlooked.

These observations and experiments point to the conclusion that the memory pattern may be of assistance in general location, but that the sense of smell is depended upon and is highly accurate in locating particular nuts.

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WINTER RODENT POPULATIONS IN FIELD-SHOCKED CORN[1]

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The present trends in agriculture and soil conservation call for many changes in land use. Many of the recommended practices are such as to bring about pronounced alterations of farm habitat. The effects of such newly created conditions on the populations of farm wildlife are being studied by the Game Division of the Department of Conservation at the Rose Lake Wildlife Experiment Station in Clinton County, Michigan. Since the smaller rodents are economically among the most important animals on the farm, every opportunity is being taken to obtain information on them.

This report summarizes information obtained on the composition of rodent populations in shocks of winter-standing corn; the distribution of certain species in the fields; winter sex and age ratios; and weights of the most abundant species. During the week of Jan. 17 to 23, 1941, all mice in 27 acres of shocked corn were collected for study. More than 500 were obtained, chiefly the prairie deermouse (*Peromyscus maniculatus bairdii*), and the meadow vole (*Microtus p. pennsylvanicus*). Pertinent observations over one year have also been included as they relate to these data.

[1] The author acknowledges the aid of several members of the Station Staff who made field collections and helped otherwise. Director Durward L. Allen made suggestions for the study and preparation of the manuscript, and Philip S. Baumgras gave considerable help throughout the work.

Areas Studied

In the three larger fields, 315 shocks were examined, and 479 mice taken. The average minimum population was 1.5 mice per shock, and the greatest number under any one shock was 11, all meadow voles. The mean number of mice was nearly the same for all fields, but the composition of the population varied significantly so that the three main areas, and the population composition in each are described separately.

Field 1, a 4-acre cornfield, was cut and shocked during late September. It was well-drained and surrounded by idle land. On the west it was bordered by a sparse sod of Kentucky bluegrass (*Poa pratensis*) containing scattered sweet clover (*Melilotus alba*) and mullein (*Verbascum thapsus*). On the south there was a 50-foot strip of sod, and beyond this a swale vegetated largely by elderberry (*Sambucus canadensis*), red-osier dogwood (*Cornus stolonifera*), and aspen (*Populus tremuloides*). To the north lay an old field of alfalfa, and to the east a lush growth of bluegrass partly overgrown with dewberry (*Rubus procumbens*) and raspberry (*Rubus idaeus strigosus*).

Fields 2 and 3 (Fig. 1) together comprised a strip-cropped area of 24 acres. Both were cut during the last week of September, when about half of the corn was removed, and the remainder shocked. These two fields were directly adjoining, but certain features of topography and the surrounding habitat

Fig. 1. Fields 2 and 3, showing the distribution of the animals collected and placement of experimental shocks.

types made the plots significantly different. Differences in composition of the rodent populations reflected the dissimilarities.

Field 2 of 10 acres, mostly on high, well-drained ground, was bordered on the west by a similar field of strip-cropped corn, on the south by an ungrazed oak-hickory woodlot and a field of old alfalfa, and on the north by a year-old field of alfalfa. The north half of the east border was continuous with field 3, and the south half bordered a plot of pastured clover.

Field 3, the largest studied, was of 14 acres, bounded on the west by field 2, and on the north by a year-old alfalfa seeding and wheat stubble field. On the east it bordered a retired timothy hayfield and on the south a fence heavily overgrown with grape with a field of red clover beyond. It contained several moist depressions.

SPECIES INTERRELATIONS

The mammals from the corn shocks in order of decreasing abundance were: meadow vole (*Microtus p. pennsylvanicus*), prairie deermouse (*Peromyscus maniculatus bairdii*), house mouse (*Mus m. musculus*), pine vole (*Pitymys pinetorum scalopsoides*), woodmouse (*Peromyscus leucopus noveboracensis*), Cooper lemming-vole (*Synaptomys c. cooperi*), short-tailed shrew (*Blarina brevicauda talpoides*), and Norway rat (*Rattus norvegicus*). Other animals known to have used the shocks for food or cover or both included the cottontail rabbit (*Sylvilagus floridanus mearnsii*) fox squirrel (*Sciurus niger rufiventer*), red squirrel (*Tamiasciurus hudsonicus loquax*), ring-necked pheasant (*Phasianus colchicus torquatus*), and the weasel (*Mustela frenata noveboracensis*).

HABITAT PREFERENCES

The prairie deermouse was the commonest species taken in field number 1, constituting 41 per cent of the total catch (Fig. 2). This small field was a solid planting of corn, well-drained, and surrounded by idle land. The meadow vole was most numerous in fields 2 and 3; in the former, principally upland

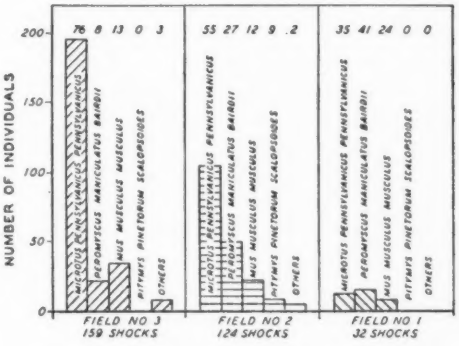

Fig. 2. Composition of rodent populations in the three fields. Figures over the species columns are percentages of the total catch.

and bounded on three sides by alfalfa sod, the meadow vole represented 55 per cent of the total catch, and the prairie deermouse 27 per cent. Field 3 had comparatively less edge than field 2, being larger and more nearly square. It also contained more low, moist areas. In field 3 only 8 per cent of the animals were prairie deermice, and 76 per cent were meadow voles. These results seem to indicate a preference by the prairie deermouse for high, dry ground in diverse crops. The meadow vole, on the other hand, occurred in greatest relative numbers in the lower, moister situations, and was more tolerant of "one crop areas." Blair (1940a) found, by live-trapping, that the greatest density of meadow voles was in moist grassland.

Fig. 1. Fields 2 and 3, showing the distribution of the animals collected and placement of experimental shocks.

The woodmouse was common in some woodlots near the study area but only six were taken and in no case at any appreciable distance within the periphery of a field (Fig. 1). Three of them were captured within 40 yards of an oak-hickory woodlot and within 10 yards of a brushy fence line. The other three were 200 yards or more from the nearest woodlot but less than 10 yards from a shrubby fence row between two woodlots that supported high populations of the woodmouse.

The finding of two or more species of mice under some shocks indicated a fair degree of tolerance between species where there is no appreciable competition for food. The presence of occupied nests of both the meadow vole and prairie deermouse in the same shock further indicates that under these conditions the two species will live together in practical harmony.

More than 60 weasel scats were observed in and immediately around one shock, indicating that one or more weasels had spent several weeks there. Scattered *Microtus* fur was conspicuous, but no sizeable remains of prey were found. Carcasses of two *Microtus* killed in the characteristic weasel manner were seen nearby several weeks before the scats were noted. Polderboer, Kuhn, and Hendrickson (1941) found that the meadow vole furnished the bulk of the prey for *Mustela frenata* in central Iowa. No detailed analysis of the scats obtained in the present study was made but the weasels' diet was obviously almost exclusively of mice, remains of meadow vole being most frequent.

ECONOMIC CONSIDERATIONS

The importance of the fieldmouse to agriculture has been discussed by many authors (Lantz, 1905, 1907, 1918; Piper, 1909; Bailey, 1924; Hatt, 1930; Allen, 1940; Hamilton, 1940). The significance of high populations of the prairie deermouse, however, appears to be less appreciated. Laboratory experiments in the present study showed that the prairie deermouse, when fed on shelled corn, required a smaller daily ration than the meadow vole. From field observations, however, it was apparent that the more highly developed storage traits of the deermouse result in the shelling out of quantities of corn far in excess of actual needs. Many caches containing as much as a peck of shelled corn indicated that large losses may accrue from the work of this species. Corn caches of the meadow vole were not nearly so numerous and damage by this species resulted largely from corn actually consumed.

CORN DAMAGE EXPERIMENT

A few figures on corn loss by mice were obtained coincidentally in an experiment to measure the use of winter shocked corn by wildlife. Ten pairs of shocks were set up late in November in fields at varying distances from cover. One of each pair was completely covered with wire netting to exclude game animals (rabbits, pheasants, and fox squirrels in this region). The second shock, beside the first, was left unprotected and so was available to both mice and game species. Eight such pairs were placed at intervals in and near field 3 (Fig. 1), three from the center to the east border, and five more on an old timothy sod into the brushy edge of a marsh. Two other shocks were set in fields away from the mouse-study area.

Only the 10 screened shocks will be discussed here. When placed, the original amount of corn present was estimated by husking and shelling the corn in two other shocks; this weighed 52.7 and 51.7 pounds, respectively. Each shock therefore was assumed to contain 52 pounds. The experiment was terminated in the last week of April when the corn remaining in each screened shock was shelled out and weighed. The losses from mice alone were as follows:

Shock no.	*Losses*	
	Pounds	*Percentage*
1	9.75	18.7
2	10.0	19.2
3	6.5	12.5
4	18.4	35.4
5	21.5	41.3
6	18.25	35.1
7	25.25	48.6
8	44.5	85.6
9	18.75	36.1
10	21.0	40.4
Total	193.9	Average 37.3

The average loss in all screened shocks was 19.4 pounds, or 37.3 per cent. The yield of experimental shocks in fields of standing shocked corn indicated that an average of 8.75 pounds of shelled corn or 16.8 per cent of the original amount in each had been consumed or lost to the farmer. The seven test shocks in grassland lost an average of 23.95 pounds or 46 per cent to mice.

An abruptly larger loss occurred in shocks 4 to 8 in the retired timothy hayfield, being three times as great as that in the cornfield. Furthermore, the amount of corn taken by mice increased in shocks with nearness to the marsh meadow; in shock 8, on the edge of the marsh, 85 per cent had been destroyed.

The average corn loss for all the unscreened shocks to which both small rodents and game animals had access, was practically the same as in those screened to admit only mice. The amount taken by game was, therefore, negligible. Substantial winter populations of pheasants, rabbits and fox squirrels were present in the general vicinity, but the absence of heavy cover areas near the field evidently discouraged use of the available corn by these larger forms of wildlife.

BIOLOGICAL DATA

Burt (1940), in discussing the home range of small mammals, stated that "the size of the area occupied by any animal is limited by the animal's ability to travel and its necessity for food and protection." Blair (1940b) suggests that "at times of great abundance of food, a mouse would have to range only a short distance from its nest to feed, but at times of scarcity it might have to range over a relatively large area." The pronounced effect of a superabundance of food and cover on an animal's activity was apparent in this study.

Observations in the fields of shocked corn during periods of snow showed that the prairie deermouse moved only sparingly from the shocks. The nearly complete absence of tracks during some periods suggested that individuals of this species remained in the same shock for several days at a time. In adjoining fields of wheat stubble at the same time many of the inhabitants had moved 200 to 300 feet from the nest in a single night. Subnivean runways of the meadow vole were sparse around the shocks and much less extensive than in surrounding meadows.

PRAIRIE DEERMOUSE

Breeding. Blair (1940) gives the breeding season of the prairie deer-

mouse in southern Michigan as early April to the last of October, with peaks in spring and fall. As further evidence that breeding does not begin before early April, he states that trapping over

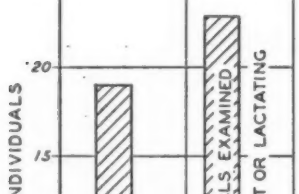

Fig. 3. Number of *Peromyscus maniculatus bairdii* pregnant in two weight classes.

twenty acres resulted in a catch of but one immature individual before mid-April. The present study afforded examination of 41 females taken in mid-January; 8 or 20 per cent were pregnant or had litters, and of the females weighing 16 or more grams, 7 of 23, or 30 per cent, pregnant or lactating (Fig. 3).

A sizeable percentage of all the deermice handled were low in weight (Fig. 4), showing that some breeding had been in progress during the previous month or two. This would suggest that a plentiful supply of food and cover has a pronounced effect on its breeding, and in such situations breeding may continue through the winter months. The average number of embryos in six pregnancies was 5.2, the largest being 7, and the smallest one. This mean is appreciably higher than the average of 4 found by Svihla (1932) in a laboratory stock and by Blair (1940b) in the field.

Sex ratio. Differences in activity between the sexes of some species often make it difficult to learn the true sex ratio by live-trapping. Townsend (1935), in dealing with the woodmouse, ascribed the greater number of males taken in trapping to their "roving nature." Burt (1940) also suggested that more extensive wanderings of males of that species might account for the greater percentage trapped. The wholesale collecting of all individuals present in an area, as done in the present study, would seem to have the merit of giving a reliable sex ratio. In 82 prairie deermice taken the sexes were equally divided. The weight range for these 82 individuals is given in Fig. 4. The average male weighed 17.5 grams and the average female 16.2 grams. The lightest and heaviest males weighed 7 and 22 grams respectively, and the extreme weights for females were 7 and 24 grams.

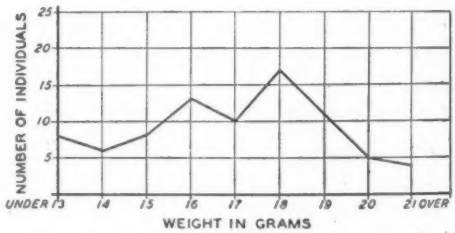

Fig. 4. Weight curve for *Peromyscus maniculatus bairdii* (both sexes).

WOODMOUSE

Only six woodmice, were collected, even though woodlots heavily populated by the species were near the fields studied. This small number in-

dicates the extent to which this species is restricted to a certain type of habitat. There were three males and three females; one of the latter contained four very young embryos. This is apparently earlier than any pregnancy record found by Burt (1940) or Nicholson (1940) who give March as the beginning of the breeding season.

MEADOW VOLE

Breeding. No pregnancies or indications of breeding were found for meadow voles weighing less than 19 grams. Of females weighing up to 26 grams, only 5 of 68 (7%) were pregnant or had litters, whereas 52.6 per cent of all those weighing 26 grams or over were pregnant or had recent litters. Of all females examined, 64 of 150 (42.7%) were pregnant or with a litter. The incidence of

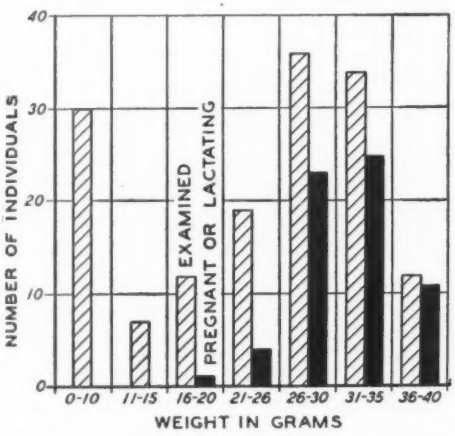

Fig. 5. Number of *Microtus* pregnant in seven weight classes.

pregnancy rose sharply among females in the 26–30 gram class and fecundity increased consistently with the weight of the females until 92 per cent of those in the 36–40 gram class were either pregnant or with litters.

Bailey (1924) found that well-fed captive females began breeding at about 25 days of age. The data of the present study indicate that wild individuals under presumably favorable

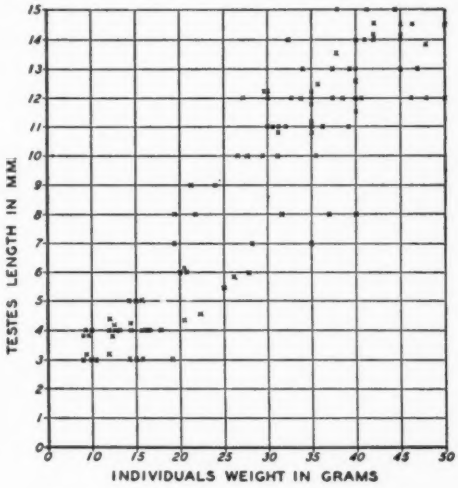

Fig. 6. Measurements of testes in 104 individuals of *Microtus*.

conditions became sexually mature at a weight of about 20 grams. The age equivalent for animals of this weight is not known, but they are somewhat less than half-grown.

Evidence was obtained that older animals have larger litters than young ones. The average number of embryos for individuals weighing up to 35 grams was 3.7 (in 38 pregnancies), the largest being six, and the smallest of one. For females weighing 36 to 40 grams the average embryo count in eight pregnancies was 5.5, the largest being eight and the smallest four. Bailey (1924) found that females breeding for the first time usually produced litters of 4, but after the first or second mating, the litter size increased to 6 and 8.

Breeding by males was found by

Bailey (1924) to begin at about 45 days of age. In the present study the weight of individuals and length of the testes was ascertained for each of the 104 males examined (Fig. 6). Few males of 30 grams or less had descended testes, whereas about half of those in the intermediate weight groups had the testes in the scrotum. Most of the mature males weighing upwards of 45 grams had the testes in the scrotum, which was usually pigmented and partially bare of fur.

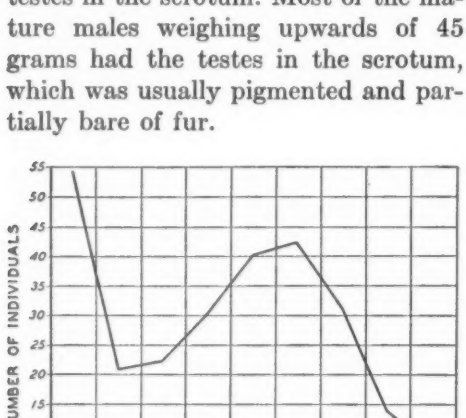

Fig. 7. Weight curve of *Microtus p. pennsylvanicus* (both sexes).

In several of these heaviest males the testes were extremely flaccid, and the tissues were glutinous in consistency. A microscopic study of one revealed no pathological condition, but an active spermatogenesis. Since this condition was observed in only the heaviest individuals, it is possibly associated with senility.

Sex ratio. The sex ratio of 288 meadow voles was 135 males to 153 females, or 88 males: 100 females. Using live-trapping techniques in studying *Microtus*, Townsend (1935) and Blair (1940a) found an unbalanced sex ratio in favor of males. The greater "wandering tendency" of the males was offered as a reasonable explanation for the capture of a greater number of this sex. The ratio found in the present study is not believed sufficiently unbalanced to be considered abnormal. The slightly greater number of females taken might still be explained by the fact that this sex has been shown to have more sedentary habits. The fact that the males range more widely might result in a larger proportion of them being out in runways and tunnels when the collections were made. Consequently, collections from the shocks alone would yield a greater relative number of females.

Weights. The average weight of 110 males was 27 grams, extremes being 3 and 53 grams. Females averaged 23.3 grams (152 individuals) or 3.7 grams lighter than the males. The lightest, female weighed 3, and the heaviest 39 grams.

The percentage of all individuals in each weight class is shown in Fig. 7. The nature of the curve suggests that breeding did not continue at a uniform rate, but that there were periods of increased sexual activity. The large number of juveniles taken in the sample and the high percentage of pregnant females indicated that an accelerated period of breeding prevailed just before and during the collections. The second peak of individuals in the 26–35 gram category is taken to mean that a similarly intensified reproductive period occurred three or four weeks previously.

About 18 per cent of the males weighed more than 41 grams each, whereas no females so heavy were taken. It is not definitely known whether this relatively large number of males was an older age group not repre-

sented in the females, or simply indicates that males reach greater size at full maturity. Bailey (1924) found, however, that no fewer than 17 litters were born to a captive female in a year. If breeding in the wild approaches this rate, earlier death of females may prevail. The continual drain on bodily vigor from rearing many litters in close succession might be sufficient to lower the normal life expectancy of females so that they would not reach the age of the most long-lived males.

DISCUSSION

Large numbers of meadow voles are always a potential threat to agriculture, but special significance attaches to abundant winter populations, when under the cover of snow, the mice cause the greatest damage to shrubs, orchard trees and other woody vegetation (Bailey, 1920; Siegler, 1937; Hamilton, 1940, 1941; Parker, 1941). It is generally known that winter breeding and accompanying high populations of meadow voles occur in some years, but the conditions responsible for breeding at that season are obscure. Baker and Ranson (1932a, 1932b) in studying factors affecting the breeding of the field mouse (*Microtus agrestis*) found that laboratory-held mice when fed a diet of winter food, "had significantly more young than the controls." They concluded, "a large supply of growing grass is not necessary for rapid reproduction in *Microtus*, although the natural breeding season corresponds roughly with the period when the growth of grass is most rapid." They also found that lowering the temperature to approximate winter conditions slowed reproduction, and concluded that the effect was upon the females since no differences in fecundity could be found between control and winter temperature males. Their studies further showed a general correlation between the exposure to light and breeding conditions. Animals held under summer conditions of food and temperature would breed if exposed to artificial light for 15 hours per day, but practically ceased breeding when the daily quota was reduced to 9 hours.

Hamilton (1941) studied the effects of temperature, light, and snowfall on the breeding season but found no correlations under field conditions. He observed that "winter-breeding individuals are taken in numbers only during a period of high population, and are seldom if ever collected when mice are scarce or merely common." Overwintering populations, according to Hamilton, include a certain number of breeding males and females that have difficulty in finding suitable mates when mice are scarce, but in large population these breeding individuals would experience little difficulty in meeting and effecting fruitful matings.

Some animals in winter undoubtedly continue in breeding condition, and litter production then would be affected by the frequency with which breeding individuals might meet. This fact alone, however, fails to explain instances of winter breeding such as noted in the present study. In the spring and summer of 1940, populations of these voles were much reduced locally. Fields of oats, wheat, clover, timothy and bluegrass pasture were live-trapped, from July 3 to September 1, for a total of 2,446 trap-nights without taking a meadow mouse. Live traps were placed

in a sedge meadow on July 22 and operated for 236 trap-nights, but no *Microtus* were taken and even sign was lacking. Field observations in late September showed that meadow mice were still extremely scarce in areas which a few months later had very substantial populations. Similarly, the removal of some corn shocks in September showed no *Microtus* in fields of shocked corn which when harvested in January supported a fair population of breeding meadow voles. Consequently it can be seen that beginning with a very low autumn population, three to four months of winter breeding had increased populations considerably. The standing population when collections were made was also breeding at a rapid rate as over 70 per cent of the females judged to be mature (26 grams or more) were either pregnant or lactating.

Causes for the sudden and sustained winter breeding by the meadow vole noted in this study are not understood, but certain points seem obvious. Breeding in several situations was initiated at a fairly low population level, and in the fields of shocked corn which might be considered a habitat of high capacity it continued at a high rate. This conforms in general with observations by Errington (1939) on muskrat populations. Moderately low populations of muskrats, when the habitat capacity is high, seemingly show greater net rates of increase than do populations of high density.

Type of food was of doubtful consequence to the voles, since winter breeding and subsequently increased populations were noted in several different habitat types as well as in fields of shocked corn. Winter climatic conditions showed no appreciable average monthly departures from normal, but a week of heavy rains early in September had the effect of re-creating much favorable meadow mouse habitat previously uninhabitable because of summer drought. There appears to be no one factor that could be cited as the cause for this unseasonal breeding, and it is suspected that this instance as well as other similar local eruptions may be explained by the action of a combination of factors not necessarily the same in all cases.

SUMMARY

Rodent populations inhabiting corn shocks on a southern Michigan farm in January, 1941, have been studied. The average minimum population was 1.5 mice per shock.

In shocks left standing in corn fields until April, 17 per cent of the corn was consumed; from shocks placed in fields covered with sod 46 per cent of the corn was removed by mice.

The prairie deermouse proved to be most common in high, well-drained situations, and the meadow vole in low, moist areas. Woodmice, common in nearby woodlots, were taken but sparingly in the corn fields.

Daily movements of both the prairie deermice and meadow voles that lived in corn shocks were greatly restricted, presumably because of the abundance of food and cover.

Mid-winter breeding was common in both the meadow vole and prairie deermouse, and one of three female woodmice examined was pregnant. The factors responsible for this unseasonal breeding are not readily apparent.

Female prairie deermice began breeding when about 15 grams in weight and the female meadow voles at about 20 grams.

A rapid recovery from a seasonal (summer) low in population was made in this area by the meadow vole during the winter of 1940–41.

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